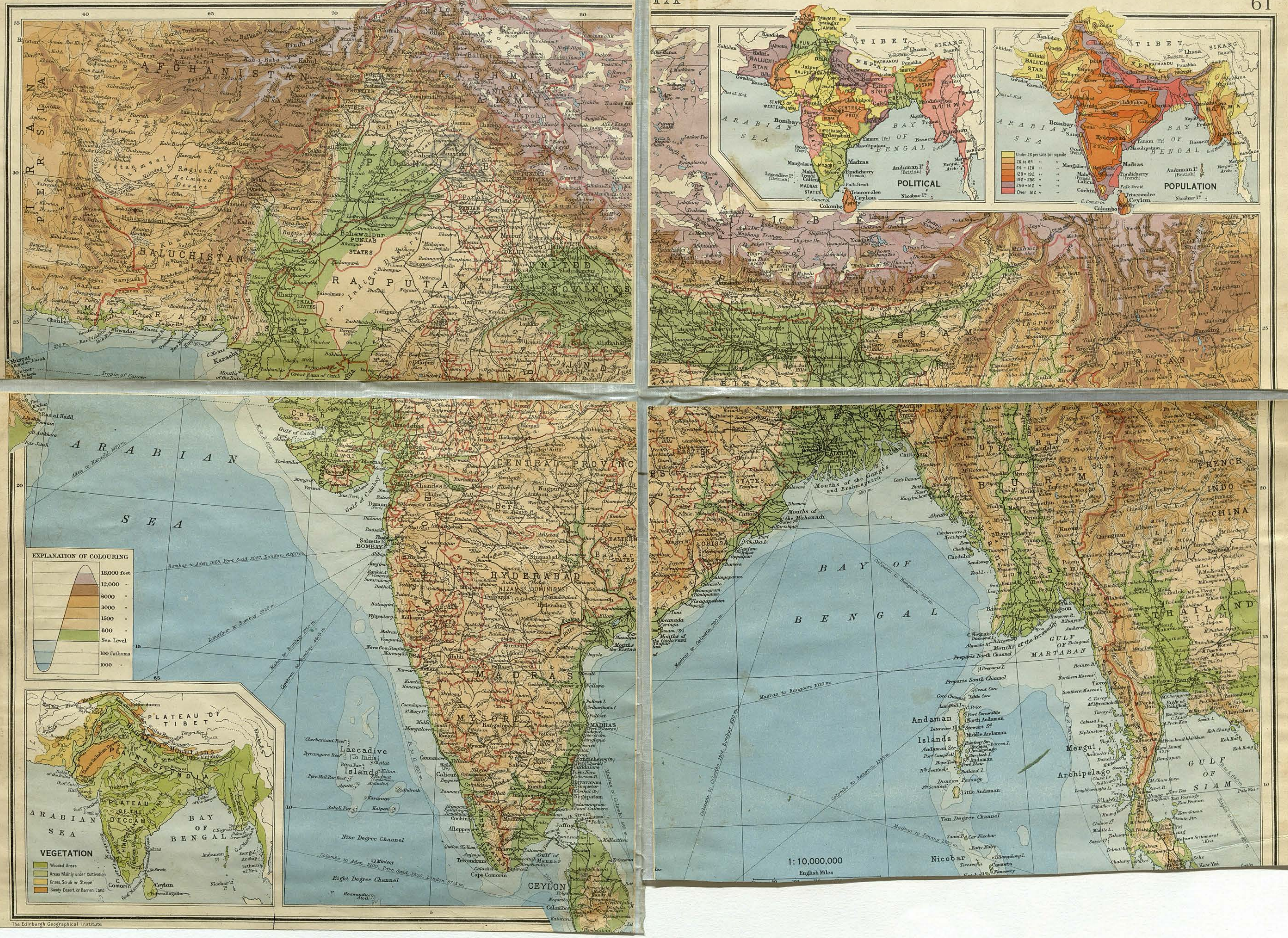
REGIONAL DIFFERENCES IN SURVIVAL, NATALITY AND MORTALITY IN BRITISH INDIA 1921-1940

A Thesis presented for the degree of Ph.D. in the University of Edinburgh.

by

ANDREW T. A. LEARMONTH.

8th June, 1953.


AFGHANISTAN
BALUCHISTAN
PUNJAB
RAJPUTANA
UNITED PROVINCES
CENTRAL PROVINCES
HYDERABAD
NIZAMS DOMINIONS
MADRAS
MYSORE
CEYLON
ARABIAN SEA
BAY OF BENGAL
TIBET
BHUTAN
ASSAM
BURMA
FRENCH INDO CHINA
THAILAND SIAM
YUNNAN
GULF OF MARTABAN
GULF OF SIAM
Andaman Islands
Nicobar
Laccadive Islands
Mergui Archipelago
Nine Degree Channel
Eight Degree Channel
Ten Degree Channel
Cape Comorin
BOMBAY
CALCUTTA
Mouths of the Ganges and Brahmaputra
Mouths of the Mahanadi
Mouths of the Godavari
Tropic of Cancer
EXPLANATION OF COLOURING
18,000 feet
12,000
6000
3000
1500
600
Sea Level
100 fathoms
1000
PLATEAU OF TIBET
DECCAN
ARABIAN SEA
BAY OF BENGAL
VEGETATION
Wooded Areas
Areas Mainly under Cultivation
Grass, Scrub or Steppe
Sandy Desert or Barren Land
POLITICAL
POPULATION
1: 10,000,000
English Miles
The Edinburgh Geographical Institute

C O N T E N T S

L I S T   O F   F I G U R E S

REGIONAL DIFFERENCES IN SURVIVAL, NATALITY, AND MORTALITY IN BRITISH INDIA 1921-1940.

PREFACE.

This is an essay in medical geography. The present writer conceives medical geography to be that branch of human geography concerned with the study of the relations between, on the one hand, health and disease, and especially regional variations therein, and, on the other hand, the physical and cultural environment. The same ground may equally well be viewed from the differing point of view of other academic disciplines - for instance social medicine or environmental medicine.

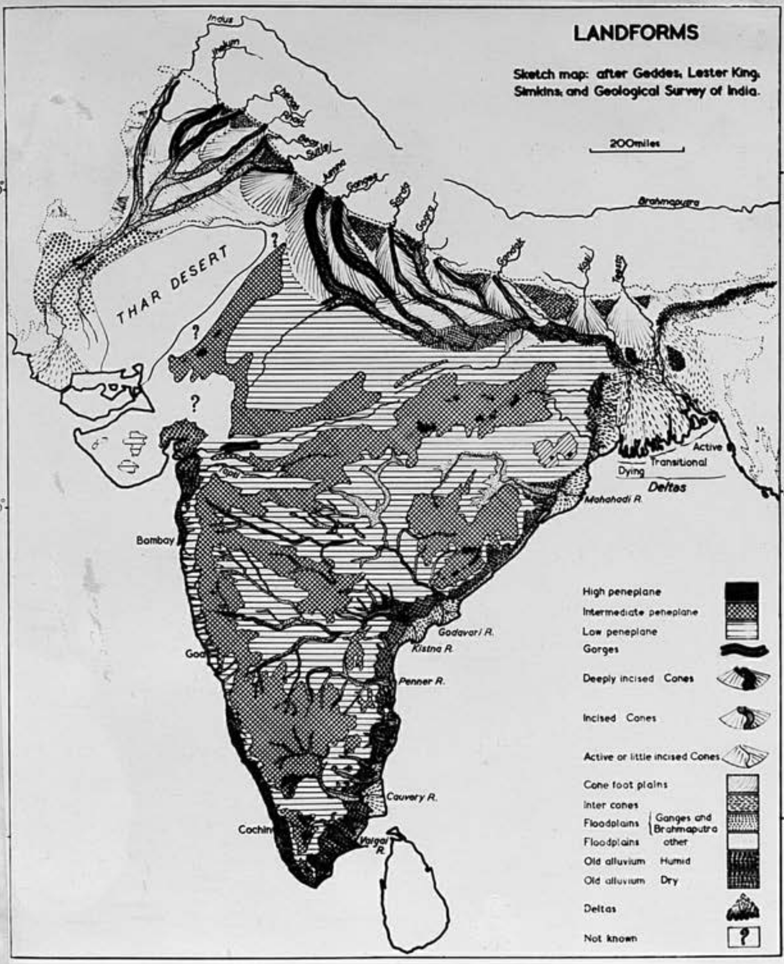
This theme, applied to India, was suggested to the writer by Professor A.G. Ogilvie and Dr. Arthur Geddes, who taught him as an undergraduate, as a possible field for three years' part-time but supervised research, suited to his training, past experience and cast of mind. In a sense, it is part of a much wider scheme of research, sponsored by the Commission on Medical Geography of the International Geographical Union, of which Commission Dr. Geddes is a member. It has become clear that the task calls for much more time, and possibly cooperation with other workers, than is convenient for the present purpose, and the essay now submitted has therefore been written to present the work done during the three years 1950-1953, despite the fact that it represents only a stage in a more prolonged project which the writer hopes to continue in the future.

Preliminary reading was done in order to select a facet of the subject to which a geographer might contribute, and the present title was chosen. Many months were spent preparing the data for suitable statistical analysis. This was aimed at an original method of mapping intensity and variability of incidence from the admittedly imperfect statistics concerning natality and mortality for the former British India, and during a recent period undisturbed by breaks in the records due to war. The resulting maps have been analysed in the light of existing geographical knowledge of the sub-continent, as well as of existing medical literature which is not perhaps well known or accessible to geographers.

To illumine the geographical analysis, the medical history of British India during the period 1921 to 1940 was reviewed by reading the annual reports of the Public Health Commissioner to the Government of India, and by reading the reports for the individual provinces in some cases, notably the Punjab. Even here, then, reading necessarily has been selective, and still more so in the case of the vast body of medical text-books and research papers with some relevance to the present topic. The writer feels that a knowledge of this literature is essential before engaging in any further original geographical contributions to this field; many of the promising lines which suggest themselves for further work would involve vast labour, and it is essential that such work should be well-directed, and avoid overlapping with existing sources. A card-index has been prepared which is at least a foundation for a bibliography relating to this subject, and in many cases the works have been read and summarised. At the time of writing, much of the literature on two topics - malaria and cholera - has been reviewed in a fairly systematic and analytical manner; as these chapters are only part of the much wider review of the literature which is in hand, they are presented as appendixes A and B respectively, rather than included in the body of the essay as was originally intended.

It will be noted that the title refers to British India, which is historically correct for the period under review. As a general rule in the ensuing text, the term British India will be used for matter dealing with statistical data, 'India' will refer to the undivided sub-continent of the period under review, and 'Indo-Pakistan', a term which is gaining wide acceptance, will be used to refer to the sub-continent in the occasional references to the years since partition. Burma has not been studied at all, although it was treated as a province of British India until 1937. Ceylon has not yet been studied in detail, but will be the subject of occasional references or analogies. Few boundary changes occurred in the period under review. They have been dealt with by treating together for the whole period, the two Districts affected by any of the transfers of territory from one District to another.

The writer has to acknowledge a great deal of assistance without which the sheer mass of the data could not have been handled in the time available. The Carnegie Trust for the Universities of Scotland has made generous grants in aid of the work, which have enabled clerical help and mechanical aids to be employed as much as possible. Advice on statistical methods was kindly given by Mr. H. Silcock, M.A., Dipl.P.A., and Miss Elizabeth Gittus of the Department of Social Science, University of Liverpool, while Miss Gittus also handled a great deal of the very heavy work of computation involved in the statistical analysis of the data; the Royal Insurance Company of Liverpool were most helpful in making a Hollerith machine available for this work. Before the statistical analysis could be carried out, the crude data had to be arranged in suitable form, and in addition fresh rates per mille of the population were calculated for each phenomenon (see p. 4); most of this work was done by the writer and his wife Mrs. A.M. Learmonth M.A., but valued assistance was also given by Mrs. H.M. Campbell, M.A., by Misses R. Leamon and M.E. Garland, and by Mr. T.L. Taylor B.A. The maps and diagrams have almost all been drawn under the writer's supervision by Mr. A.G. Hodgkiss and Mr. D.H. Birch, while those maps which have been used for teaching or have already been published by oral presentation were drawn by them in time generously allotted for the purpose by Professor Wilfred Smith, John Rankin Professor of Geography in the University of Liverpool. Throughout the three years, the writer has drawn on his official supervisors for advice, and from time to time has talked over various parts of the work with Professor T.H. Davey of the Liverpool School of Tropical Medicine, with Professor Smith, and with Colonel W.J. Robertson, Assistant Director of Medical Services, H.Q. Northern Ireland District, Lisburn. The work owes much to constant help and criticism from the writer's wife. Finally, but not least, the unstinted help of several librarians must be acknowledged - those of the High Commission of India, India House, Aldwych, London W.C.2., of the Liverpool School of Tropical Medicine, and of the Universities of Edinburgh and Liverpool. The material now presented as Chapter 11 was read at the Belfast meeting of the British Association as joint work by Dr. Arthur Geddes and the present author. The idea of using the estimates of population for inter-censal years as a variation of Dr. Geddes' earlier work, and covering a more recent though overlapping period, occurred to the present writer in the summer of 1951. He had a much valued opportunity of discussing this project with Dr. Geddes in the autumn of that year and a joint application for time to present the material at Belfast was made. Dr. Geddes was in the U.S.A. for the whole of 1952. Most unfortunately, the opportunity to get assistance with the statistical work involved did not occur until July 1952, and writing began in August. It was by then impossible to obtain Dr. Geddes' contributions to the writing which had been earlier envisaged, so that the chapter now presented is entirely the work of the present author save only for the planning stage.



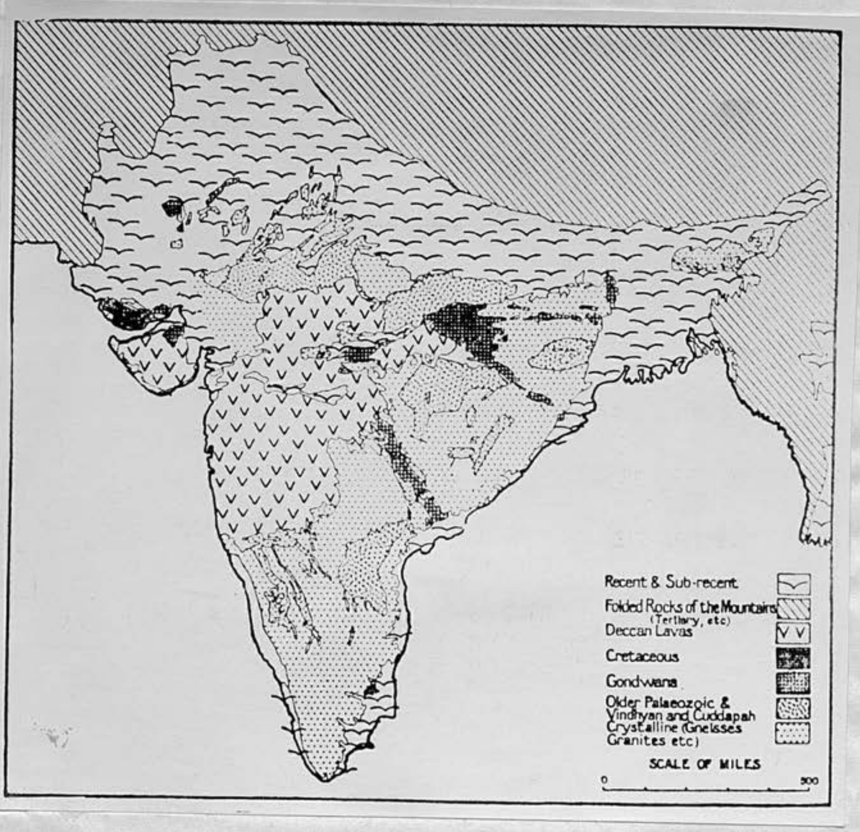
LANDFORMS
Sketch map: after Geddes, Lester King, Simkins, and Geological Survey of India.
200miles
Indus
Jhelum
Chenab
Ravi
Beas
Sutlej
Jumna
Ganges
Sarda
Gogra
Gandak
Kosi
Tista
Brahmaputra
THAR DESERT
?
Active
Transitional
Dying
Deltas
Mahanadi R.
Bombay
Godavari R.
Kistna R.
Goa
Penner R.
Cauvery R.
Cochin
Vaigai R.
High peneplane
Intermediate peneplane
Low peneplane
Gorges
Deeply incised Cones
Incised Cones
Active or little incised Cones
Cone foot plains
Inter cones
Floodplains Ganges and Brahmaputra
Floodplains other
Old alluvium Humid
Old alluvium Dry
Deltas
Not known

1.

INTRODUCTION - THE GEOGRAPHICAL SETTING.

Birth, death and survival - the length of life and something of its quality from the point of view of health - among groups of men - these are studies of mankind clearly proper to the doctor, the sociologist or demographer, or perhaps to the politician, the soldier or the actuary. The geographer's contribution to such studies lies in his analyses of the data from a particular point of view: he seeks to find out whether there are spatial or regional differences in the occurrence of such phenomena, including variations in time, from month to month or from year to year in different areas; and if such differences do exist, he seeks for correlations with factors in the physical and cultural environment, which may or may not prove to be causally related. A brief and selective account of the physical and cultural environment will be given in this introductory chapter, as a setting for the main discussion.

Indo-Pakistan is a roughly diamond-shaped land-mass of about one and a half million square miles, whose axes are in length about 3000 miles north to south and about 2000 miles east to west. It extends from 8° N. to 37° N., and from 61° E. to 98° E. It is a sub-continent, of which the southern half is peninsular in character, being a projection into a great ocean from the greatest of the land-masses - 'Eurafrasia'. Peninsular India corresponds with the South and middle of the Plateau. The



2 Geological Map..........

continental, northern half contains the dry North-west of the Plateau, extending to the Thar steppe-desert, and also one of the greatest of the world's lowland plains emerging to its great deltas in East and West. Climatically it is more continental in character, and yet is peculiarly shut off from the main mass of Asia by the great mountain barrier of the Himalaya and other ranges. The frontispiece is a relief map of India, the end-papers show the administrative divisions of India during the period under review, and figure 1 shows a tentative interpretation of its landforms except for the northern mountains.

The plateau is built mainly of ancient (pre-Palaeozoic) crystalline rocks and old sedimentary rocks, sandstones and some limestones - an 'oldland mass' and part of the postulated ancient continent of Gondwanaland. In the north-west of the plateau, however, a roughly quadrilateral area amounting to about a third of the whole, consists chiefly of much more recent basalt lava flows (late Secondary to Tertiary) see figure 2. Both old-land rocks and lava-flows seem to have been reduced to peneplanes or erosion surfaces in Tertiary times. A series of broad uplifts is envisaged as occurring since then, with long periods of relative stability. During these, the forces of erosion were able to reduce the general surface to the rolling peneplanes at several levels, which are so important to the landscape of peninsular India, and resemble a series of very broad steps with relatively shallow, steeper facets between.[1] This part of Gondwanaland was involved in great but gradual and mainly horizontal earth-movements. As Du Toit suggested, Gondwanaland moved in a roughly north-easterly direction, acting like a gigantic bull-dozer, compressing and contorting the vast depths of sediments from the former sea called Tethys, a great down-warp in the earth's crust which had received deposition from the surrounding land-masses for many millions of years. This compression produced the much greater vertical earth-movements of the Himalayan mountain-structures. One consequence of this involvement of the Plateau has been a warping of the peneplanes, so that there is a rather gradual rise from beneath the alluvium of the Indo-Gangetic plain, and with generally greater heights in the South and West of the Plateau. The old-land raft, as it seems, had plunged its blunt nose under the Indo-Gangetic trough, piling up a Himalayan wave. Heights on the Plateau are barely 1000 feet in the North, generally two to three thousand feet further South, and up to peaks of 7000 feet in the South-west. The sediments from Tethys were here compressed between the Gondwana old-land block and the relatively stable 'median mass' now uplifted as the Tibetan plateau, constructing the parallel ranges of the Himalayan 'fold-mountains', while the parallel ranges of

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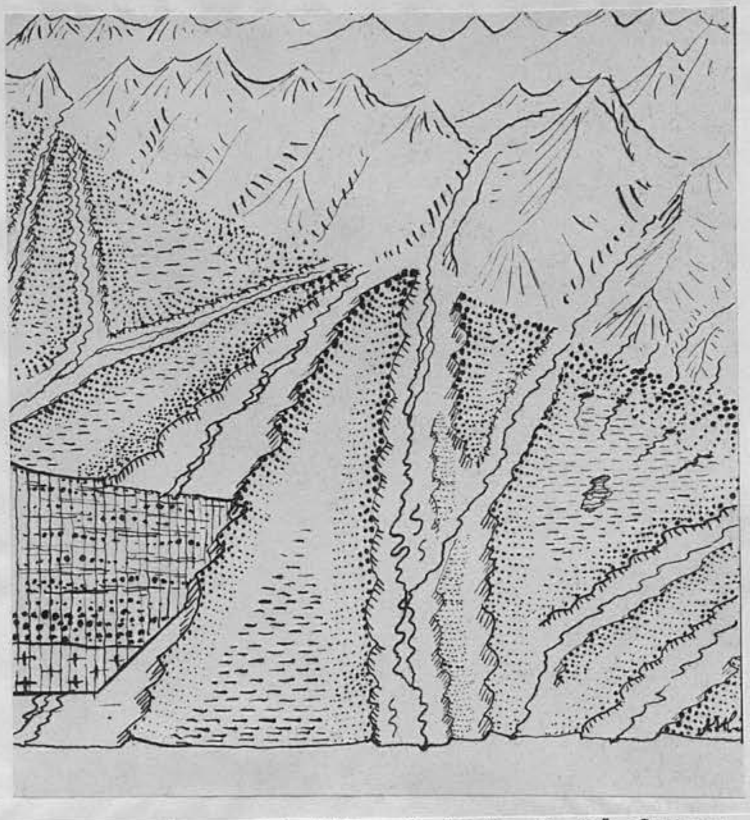
1. The mapping of these surfaces by Lester King(Q.J.G.S. Vol. cvi) is very tentative, to the point of being rash and premature, but it has been used in figure 1. This sketch map was compiled primarily for teaching purposes, and has been shown to have illustrative value, but can not be used in particular areas without further scrutiny of the evidence.

hills on the West of India and on the Burma border belong to the same period of mountain-building. The opposing stable or perhaps horizontally moving mass and ranges analogous to the Himalaya in Siberia are not relevant here. The inhabited valleys of the Himalayas vary from a few hundred feet to some 10,000 feet, while the intervening crests are of some 5000 to over 20,000 feet.

The coastal lowlands of peninsular India lie below 600 feet, and they include some low-lying erosion surfaces and long stretches of 'emerged' coastal plain of recent sediments of which the deltas are notable elements particularly in the East. However, in that part of the coastal lowlands lying at the foot of the steep westward-facing scarp of the Western Ghats and roughly between Goa and Bassein (north of Bombay City) the most recent major movement of land relative to the sea has been downward. The drowned valleys form twining, sheltered estuaries with rocky sides. All round the coasts, the sea has carried on its ceaseless work of regularising the coast-line, and has carried this process towards the stage recognised as sub-mature; thus even on the drowned coasts, the headlands have become cliffed, while the estuaries are often partly closed by sand-bars. On the emerged coasts, there is a marked tendency towards a coast-line of deltas linked by drifted sand-bars containing lagoons, especially in the South-west in Malabar and Cochin.

There remains the great lowland of the Indo-Gangetic plain, with which the Brahmaputra valley of Assam may be included. In some two thousand miles, the relief lies wholly between sea-level and a broad swelling of under a thousand feet north-west of Delhi. This is a major trough in the earth's crust, infilled with great depths of alluvium of very varied texture, the product of erosion from the plateau and especially from the massive erosion which occurred in the Himalaya even as the mountain building was in progress. The alternations between boulder, gravels, sands and silts are due to changing conditions of erosion and deposition during the many millions of years during which they have been at work, and also to the innumerable changes of course of the wandering rivers, past and present, at all stages of deposition, while erosion attacking the alluvium in turn has also an important part in land-forms and sub-soil water conditions today. It is helpful to follow a great river from the Himalayas to the sea. As it cuts across the great mountain chains, there are gorges up to several miles deep. When the river leaves the mountains, the speed of its flow is checked, and its waters, spreading and radiating widely in floods, have been unable to carry so great a load of debris, and a fan-shaped deposit of alluvium has been built out by the river whose distributaries change their courses as they are blocked by their own deposits. This fan or cone has gentle slopes which are, however, rather more marked than those in other parts of a great alluvial plain. In addition to the major slope from the gorge, minor slopes back down from each distributary. Important gradations in the texture of the surface deposits correspond to these land-forms, from boulders at the gorge-mouth to sand or



Diagrammatic sketch, land-forms of hill-foot........................

silt where the 'alluvial cone' grades gently into the main flood-plain of the river, and again from coarser to finer deposits as one moves at right angles away from the sandy spill-banks of a present or a past distributary course of the river, to spill-hollows of clay which held, and may still hold stagnant water.

Along the hill-foot of the outer ranges of the Himalaya, on either side of the gorge-mouth, the torrential, often seasonal local streams from the nearby hills have deposited numerous small cones of coarse gravels; these small cones coalesce to form a zone of coarse gravels. The texture of these gravels becomes finer away from the hill-foot giving place to clays, and since the alluvium of the main cone on either hand has also become finer towards its edge, a roughly triangular area of finer alluvial material is found, slightly depressed relative to the neighbouring cones; Geddes has called this an inter-cone.[1] The water that has percolated through the very permeable gravel zone comes to the surface at the lower and less permeable material of the inter-cone, in a line of springs or pools which mark the beginning of the wet jungle or 'terai' of much of the hill-foot zone.

After leaving the gentle slopes of the cone, the main river may be pictured in the flatter middle reaches, meandering much more markedly and more freely in the broad flood-plain of a

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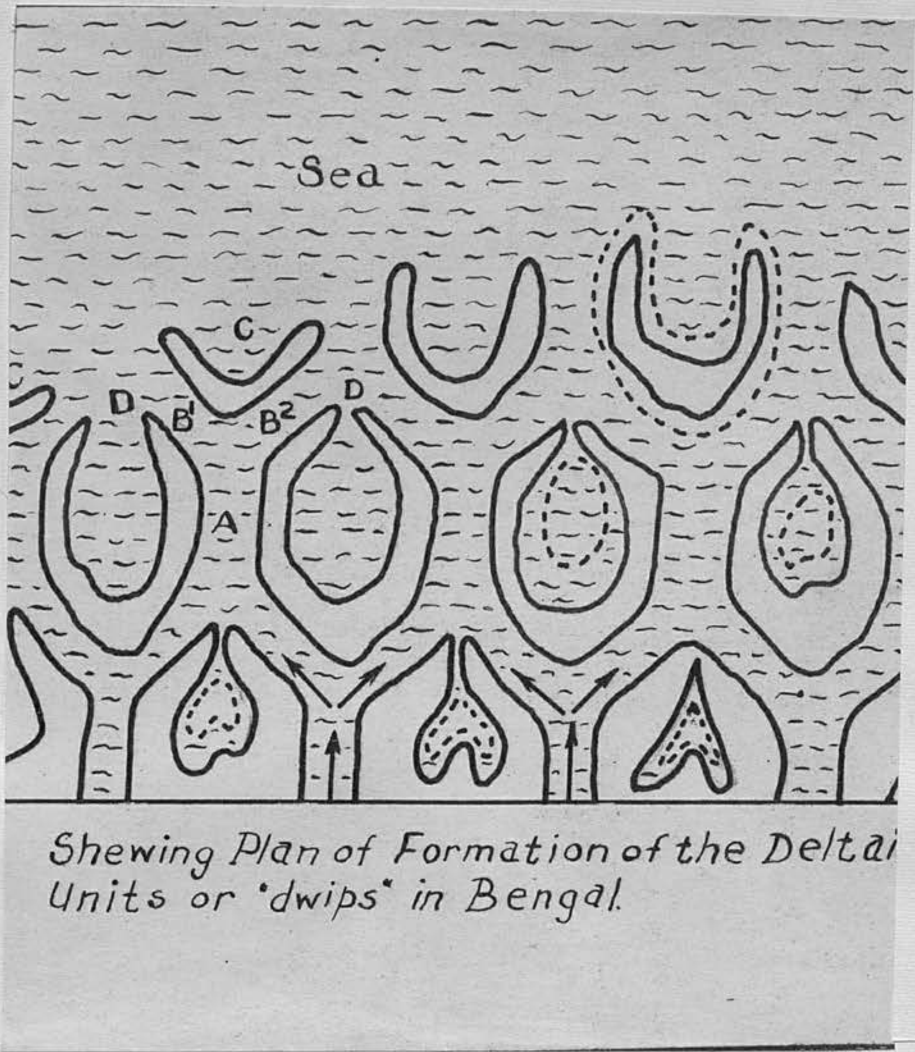
1. The whole of this section owes much to the teaching of Dr. Geddes, and to his generosity in making available the manuscript of his partially completed book on India.



4 Deltaic formation in Bengal....

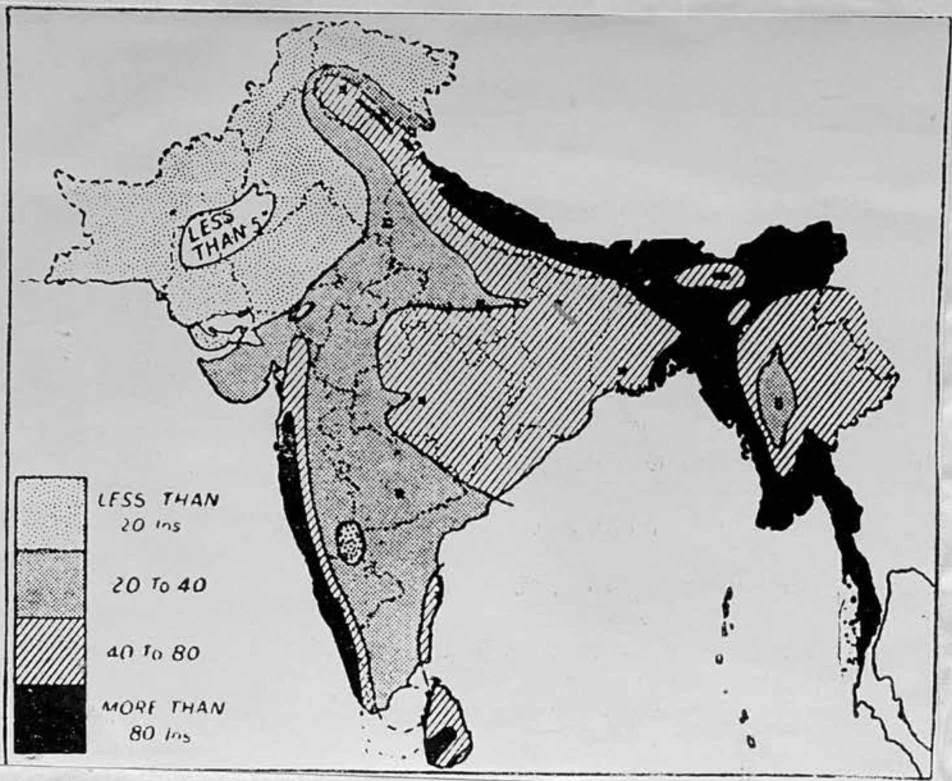
(mature) river, changing course as its meanders migrate down-stream or swing laterally, leaving ox-bow lakes and other stagnant water as relics of its recent history. Again there is an alternation in the texture of material according to conditions of erosion and deposition, and especially a change from coarser to finer deposits as the land slopes imperceptibly away from the present or past banks of the river-courses, i.e. from spill-bank (or levee) to spill-hollow; but the coarser deposits are now sand, while the finer are silts. Towards the sea the river splits into meandering distributaries in the delta which may swing across a fan-shaped alluvial area, with some analogies to the hill-foot cones, but with still gentler slopes and finer alluvium. Figure 4 shows an element of the nature of deltaic formation, where a distributary is checked on meeting the sea tides, and splits in two because of the obstacle offered by a deposit of its own alluvium, which accumulates to form a horse-shoe shaped bank of sand or silt concave to the coastline. Through further silting or artificial reclamation, this becomes one of the hollow islands like partially submerged saucers, which are typical sites of settlement and agriculture in deltaic lands.

In relating this generalised picture to figure 1, it is necessary to note that in the west the cones of the upper Ganges plain and the Punjab have been cut into by the present rivers down to 50 or 100 feet; here, the wandering of the rivers across the surface of the cones has ceased. Each river has now a relatively fixed course, and its wandering is confined to the limits of a flood plain from a mile or so to 20 miles wide in the Ravi and Sutlej incised flood plains. The upper plain has been left 'high and dry', as it were, on the main surface of the cone, and the conditions of ground-water are very different there. The cone is still seamed by former course of the main river, but these are occupied only by local streams, or may be used as drainage channels from canals. The cones of the middle Ganges basin are less incised, to a depth of some 20 feet or less, and the Gogra lacks a true cone. In the eastern Ganges plain the Kosi is still a wandering and distributing river, actively building its cone of light micaceous sands, while the Tista has only become fixed in recent generations.

The great delta of the Ganges-Brahmaputra has a western zone of dying rivers, where through drainage in the water-courses has become impeded. Three inter-acting factors have brought this about: the main egress for Ganges water has changed from westerly to easterly distributaries; accelerated soil erosion in the north-eastern part of the Plateau has overloaded the rivers with silt; and, finally, for a century past railway and road embankments have been built without adequate culverts to maintain the natural surface flow. In contrast, the eastern delta is all the more active with great sheet-floods flushing almost the whole country and renewing the fertility of the fields by depositing fresh silt. Inland, a process analogous to the incising of the hill-foot cones and widening of the flood plain has removed most of the upper surface leaving certain 'islands' of old red alluvium standing a few feet above the general level of the delta, with low fertility and important human consequences which will be mentioned later. The Indus delta is distinguished by the much greater importance of wind-blown sands.

The full importance of the land-forms is only to be appreciated when they are viewed in their complex interactions with climate, vegetation, soil, agriculture and the ecological requirements of various pathogens. Even at this stage, however, some examples may be given. In the north-western zone of dissected cones, the relatively high water table in the ribbon of flood-plain results in malarial conditions much more nearly approaching endemicity compared with the broad upper plain which has mostly a much lower water-table; in the swampy forest and grass 'terai' of the hillfoot zone, especially of the middle and eastern plain, colonists moving in from the plain and the mountains to tame the wild find themselves in conditions of very severe malarial infestation.

The greatest single endemic home of cholera is in the Bengal delta, while lesser endemic foci are in other deltas and in the great flood plain of the middle Ganges; it will be shown that the high water-table and high organic and saline content of the waters, are peculiarly favourable to cholera with interesting exceptions at some times and in some places (see p. 45) and the general discussion in Appendix B). Less directly the variations in soil texture and ground-water conditions in the Indo-Gangetic plain are related to capacity for irrigation and to the differing staple crops within the climatic possibilities, and therefore have a bearing on the health of the people. Thus in the ↄ 5. Mean annual rainfall....



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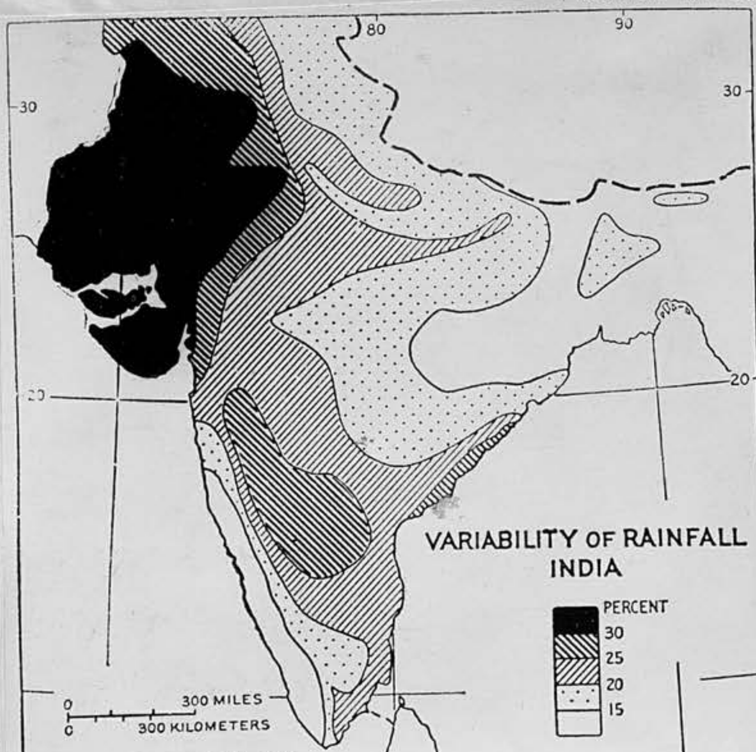

FIG. 87A.—The variability of rainfall in India (after A. V. Williamson).

Middle Ganges, the flood-plains and inter-cones are used more for growing rice, the cones or upper surface more for maize and potatoes. Or again in Malabar, the different belts of soil texture and soil development under a wet monsoon climate have different potentialities for cropping. Use of the old alluvium includes the production of manioc, so greatly increased in the last 50 years, with consequences for the demographic and medical complex comparable to the impact of the potato in cooler areas (see also p. 73).

The monsoon dominates almost every aspect of Indian life by its seasonal rhythm and its vagaries. There is no greater single factor in the medical geography, and yet, as will be seen, studies specially directed towards the relations of climate with health and disease cover only narrow segments of the field, and are seldom very satisfying. For the purpose of this introductory chapter, it may help to examine a simple rainfall map (Stamp 1944), a map of the variability of rainfall (Williamson 1931) and a map of climatic regions (Stamp/Kendrew). The rainfall map offers quite striking correlations with elements in medical geography: thus the area with over 40 inches of mean annual rainfall is associated through rice-growing with the dense population and general ill-health of the poor and malarious rice-eater, and offers correlations with diseases as diverse as leprosy and hookworm, although clearly the causal links require much more thorough examination. The relative constancy or variability of rainfall is at least as significant, affecting medical geography, for instance through famines and the near-

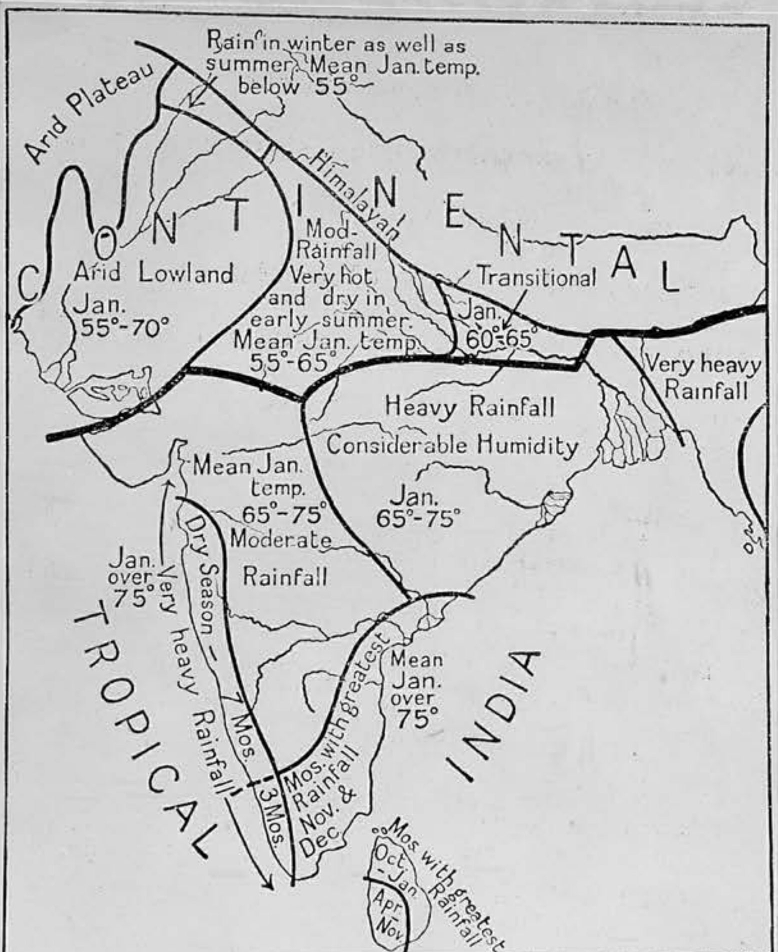

Fig. 88.—The climatic regions of India.

The divisions shown on this map are modified from those drawn up by Kendrew. In particular th fundamental separation of 'Continental India' and 'Tropical India' was suggested to the writer b Kazi Saied Ahmad.

7.

famines which are equally important. A considerable degree of variability from year to year occurs in these very zones where decreasing rainfall gives conditions only marginal to the requirements of certain staple crops - about 40 inches mean annual for rice and about 20 inches mean annual for millets. The whole basis of life is therefore unstable, and there is indeed almost a state of 'conditional instability', in which, as by trigger action a whole complex of ills may be set in train by the occurrence of any one of a number of adverse events such as a severe flood or drought, two successive crop shortages, an epidemic of plague, influenza, or malaria, or of course a combination of these disasters. The map of climatic regions has a fundamental division into tropical, mainly peninsular India, and continental, northern India, based largely on the occurrence of a well-marked cool season in the latter. For this reason, continental India is mainly the region of wheat, cultivated in the cool season, with important consequences for nutrition. The sub-divisions are chiefly by isohyets important for cropping, but the character of temperature, humidities, seasonal incidence of rain and length of dry season are indicated where these are of particular interest. Read along with the map of variability of rainfall, it is invaluable in getting a first broad view of regional climates.[1]

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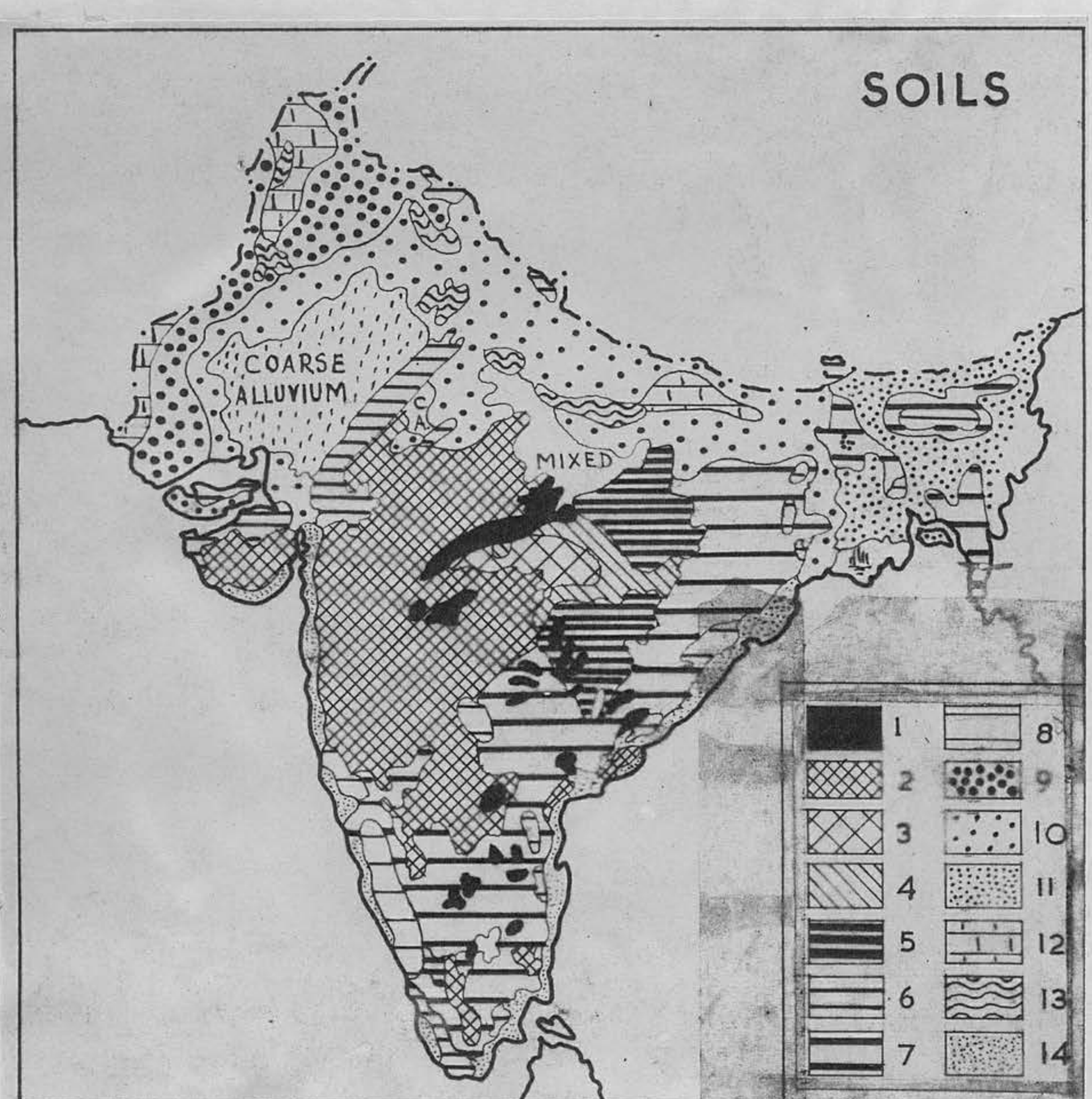
1. The Meteorological Atlas of India 1906 is still valuable in following month by month the changes as the monsoon advances and retreats in mean temperatures, maximum temperatures, minimum temperatures, rainfall, relative humidities at 8 a.m. and 4 p.m., and also absolute humidities.



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Key to Figure 8

1 Deep black soils
2 Black clayey soils
3 Black loamy soils
4 Black sandy soils

5 Red sandy soils
6 Brown sandy soils
7 Red and yellow soils
8 Dark reddish brown soils (lateritic)

9 Indus alluvium
10 Gangetic alluvium
11 Brahmaputra alluvium

12 Calcareous soils
13 Alkaline soils

14 Coastal alluvium

The broad soil-type towards which the soils of most of India are developing seems to be some form of laterite, no doubt modified by greater leaching mearer the equator, and by less leaching towards the desert margins. The zone of black-earths, which one would expect is mainly though not entirely associated with the country of basalt lava flows, on which they may develop more quickly. A map of soils is reproduced as figure 8 . It is clear that in the peninsula and especially on the Plateau the time taken for the several peneplanes to develop has allowed a much greater advance towards the climatic soil-types than has occurred in the Indo-Gangetic plains which indeed are simply marked as dominated by the alluvium of one or other river. Even here, however, the 'old alluvium', some important areas of which are distinguished in figure16, has advanced markedly towards the climatic soil-type in the eastern plain. In general, the change towards a lateritic soil, such as takes place in pluviose India, is a change unfavourable for man's activities compared with the immature soil developed on recent alluvium. In drier areas, with less leaching, this implication can not be made.

The climatic disadvantages of the less pluviose and more variable areas are to some extent evaded by means of irrigation, the chief areas of which are shown in figure 9 . The distinction between the great modern engineering works of the last sixty years and the small-scale indigenous works of the 'tank country' of southern India should be noted.[1] Both types enable one year's

1. The word 'tank' is adopted from one of the Indian languages, and simple means any artificial sheet of water.

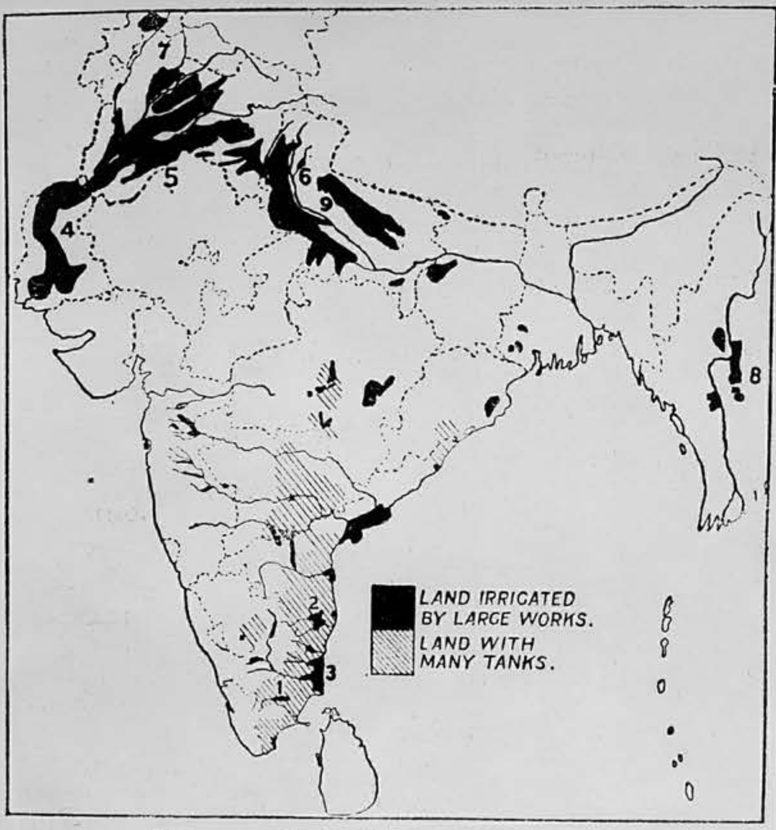


FIG. 90.—Irrigation map of India.

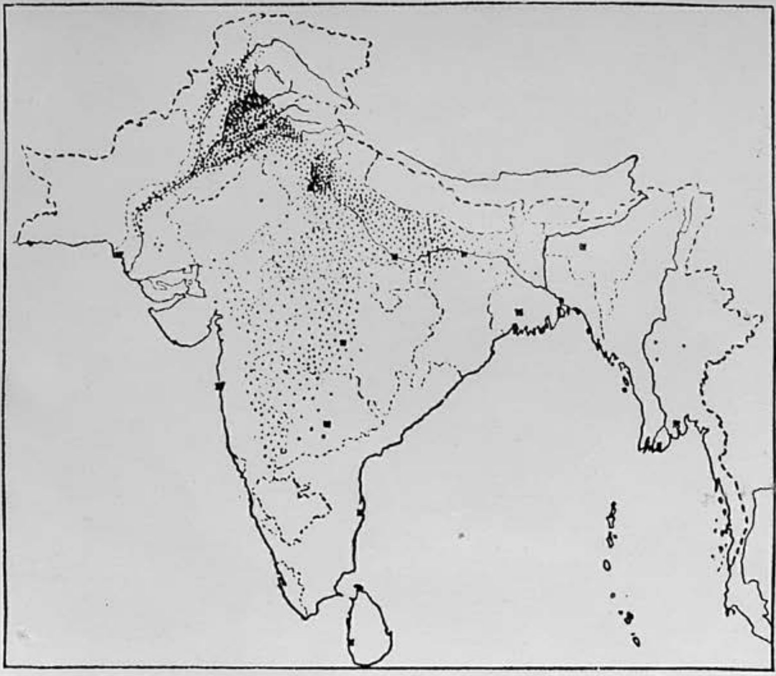
Periyar system.
Cheyyar, Poini and Palar system.
Cauvery Delta system.
Sind (Lloyd Barrage scheme).
Punjab.

6. Ganges-Jumna systems.
7. Vale of Peshawar.
8. Dry Belt of Burma.
9. The Sarda Scheme.

9

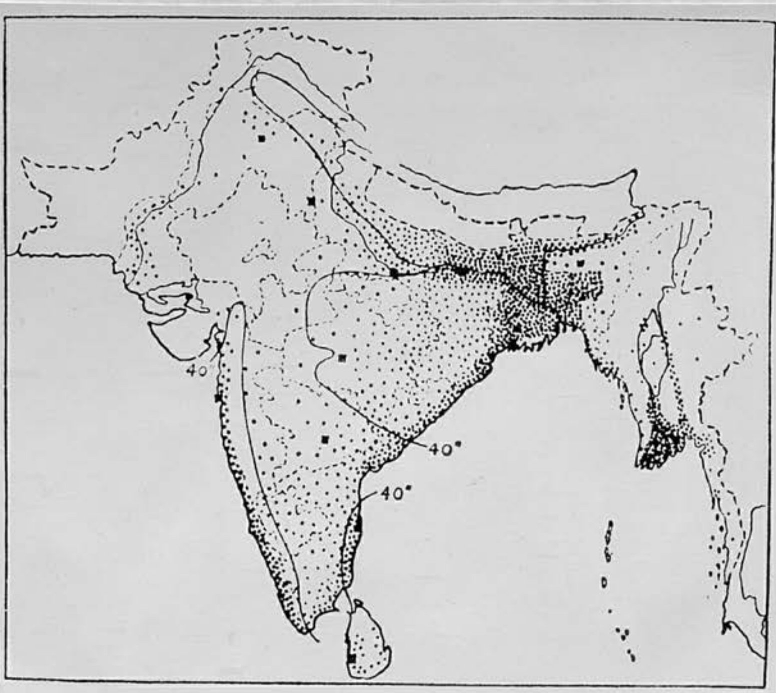
rains to be used over a longer season, and insure against a lull in the Monsoon but because of the high evaporation, tank water can not be stored in a good year against a year of poor rainfall.

The farmers who cultivate these lands under the conditions described, are mainly peasants, owning or working tiny but individual though often scattered holdings. Share-cropping is very prevalent in parts, and the ratio of landless labourers to others seem to be increasing everywhere. Many peasant farmers are in the hands of money-lenders, although co-operative farming is a promising possible remedy in some areas. Everywhere cattle are reared, roughly one for every two people, although there are more in the north-west, in proportion to the population. Cattle are revered by Hindus, and never eaten except by untouchables, while many Muslims regard cattle as wealth, numbers being esteemed rather than quality. Cattle are used for tilling and for draught purposes, but are so poorly bred and fed that they yield little milk, and only a little meat when killed in old age by Muslims. There is no yield of meat to the Hindus because of religious tabus, except to the untouchables who eat the carrion when the cattle die. The staple cereal crops are mapped in figures 10 to 12. Rice cultivation, except for irrigated areas, is in the area with over 40 inches of rainfall, but markedly in flood-plains, deltas and coastal plains. Wheat cultivation is often grown as a dry crop, but its cultivation is concentrated in the north-western areas of canal and well irrigation; yet it stretches in important quantities eastwards into the



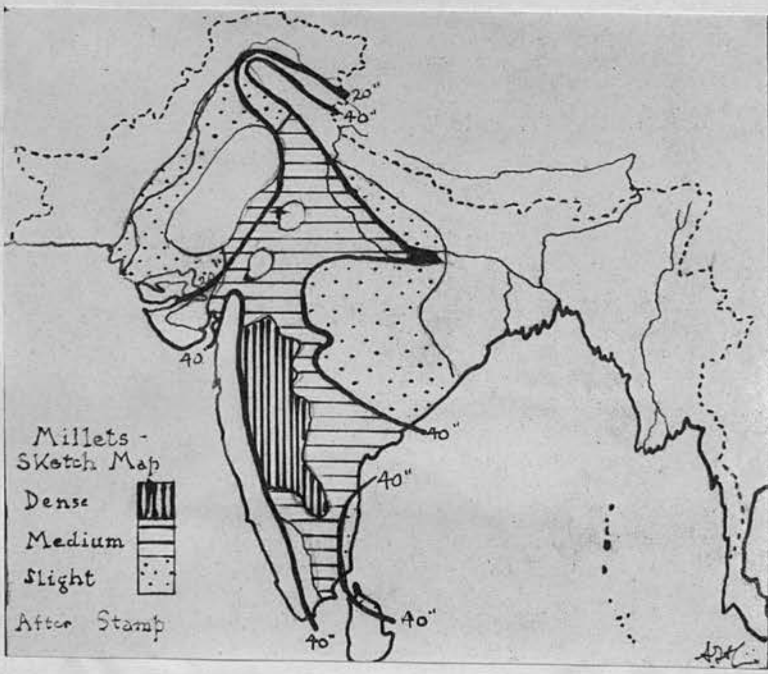
11.

95.—The distribution of wheat in India, showing the concentration i
Punjab and United Provinces.



10.

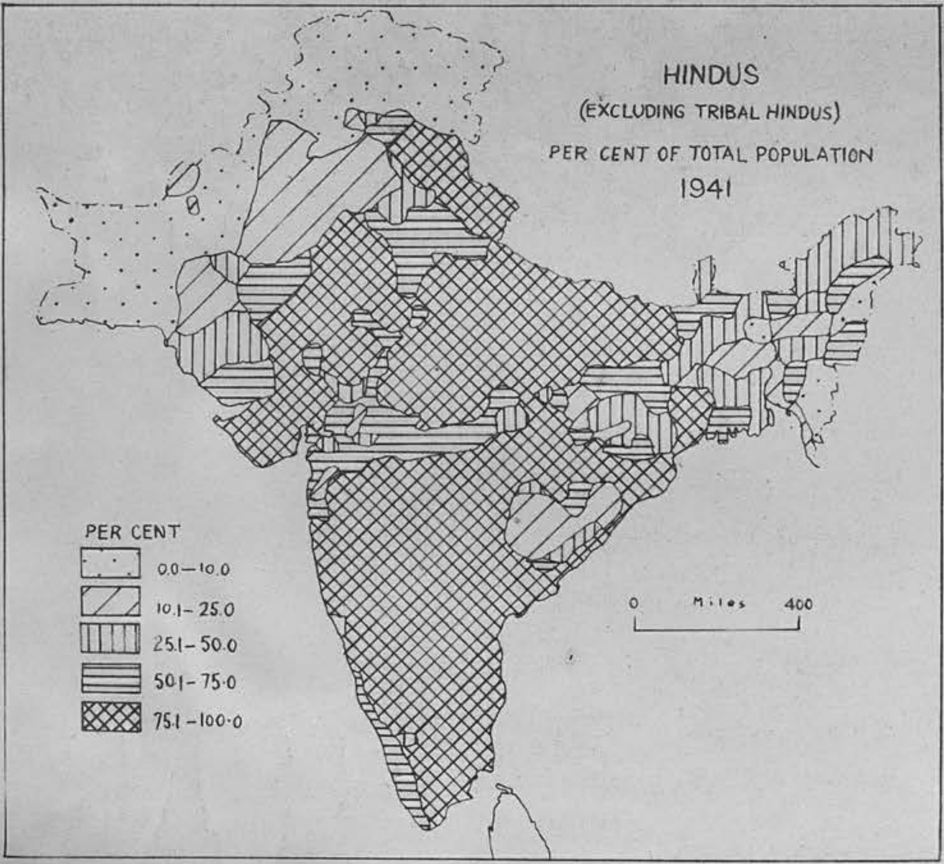
FIG. 94.—Map showing the distribution of rice in India.



Millets -
Sketch Map
Dense
Medium
Slight
After Stamp
20"
40"
40"
40"
40"
40"
40"

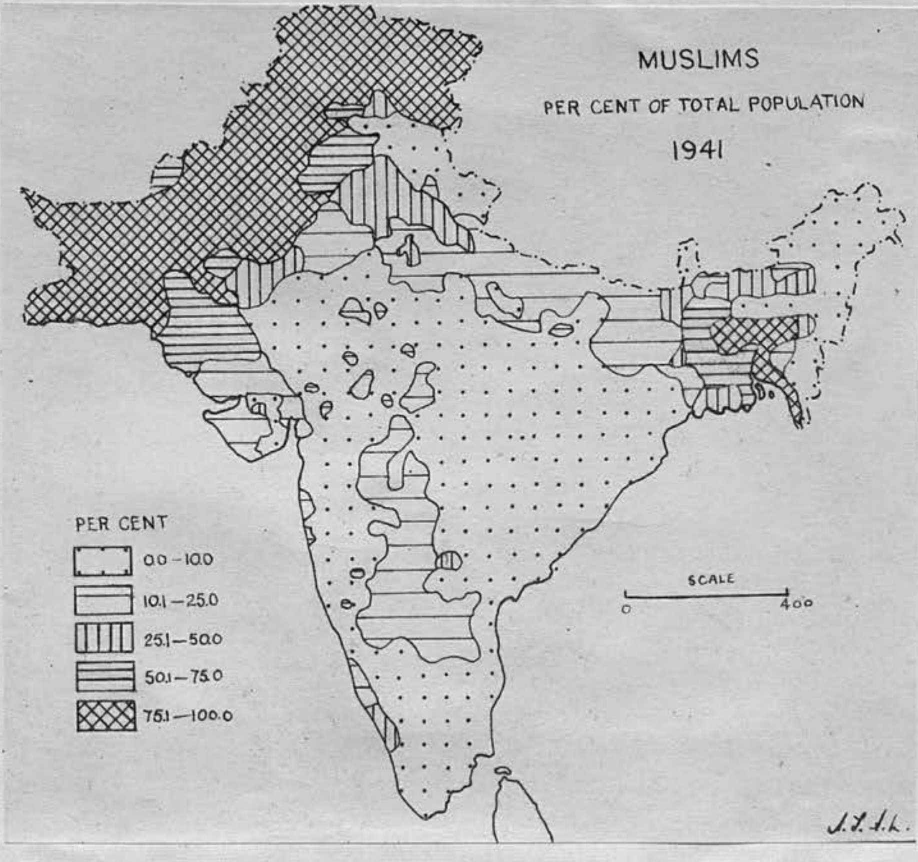
lower-middle Ganges basin, and southwards on the plateau to about 15° N. The millets are at their densest on the black cotton soils of the west-central Plateau, but are important everywhere between the 20 inch and 40 inch isohyets. Maize is important along the hill-foot of Punjab, in a wider zone in the middle Ganges basin, and on the plateau roughly north of the Tropic. In the absence of appreciable animal sources of fats, the cereals are accompanied by small amounts of varied oil seed crops, including sesame, cotton-seed, linseed, rape, mustard, and groundnuts although these are largely exported, and similarly to supply protein, small quantities of many kinds of legumes are grown. Cash crops are grown everywhere, in part of the peasants' plots, to pay taxes, rent and interest to moneylenders, and to meet the cost of marriage feasts and cash purchases; they include the best qualities of rice, groundnuts in the South-east, spices and coconuts in the South-west, cotton on the north-western plateau and in smaller areas elsewhere, wheat in the North-west, jute especially in the eastern Bengal delta. Sugar is a very common cash crop used to pay water-dues in an irrigation area. Plantation crops, rubber, coffee and tea are grown at appropriate altitudes in the South-west, and tea in the North-east, on the gentle slopes of the Brahmaputra valley and on hill-sides to almost 6000 feet. It should be said that the plantations or tea-gardens have mostly gone as pioneering undertakings into wilderness.

Some 65 per cent of the people are directly dependent on the land, and 80 per cent are village dwellers. The rest include the


HINDUS
(EXCLUDING TRIBAL HINDUS)
PER CENT OF TOTAL POPULATION
1941
PER CENT
0.0—10.0
10.1—25.0
25.1—50.0
50.1—75.0
75.1—100.0
0 Miles 400

13.

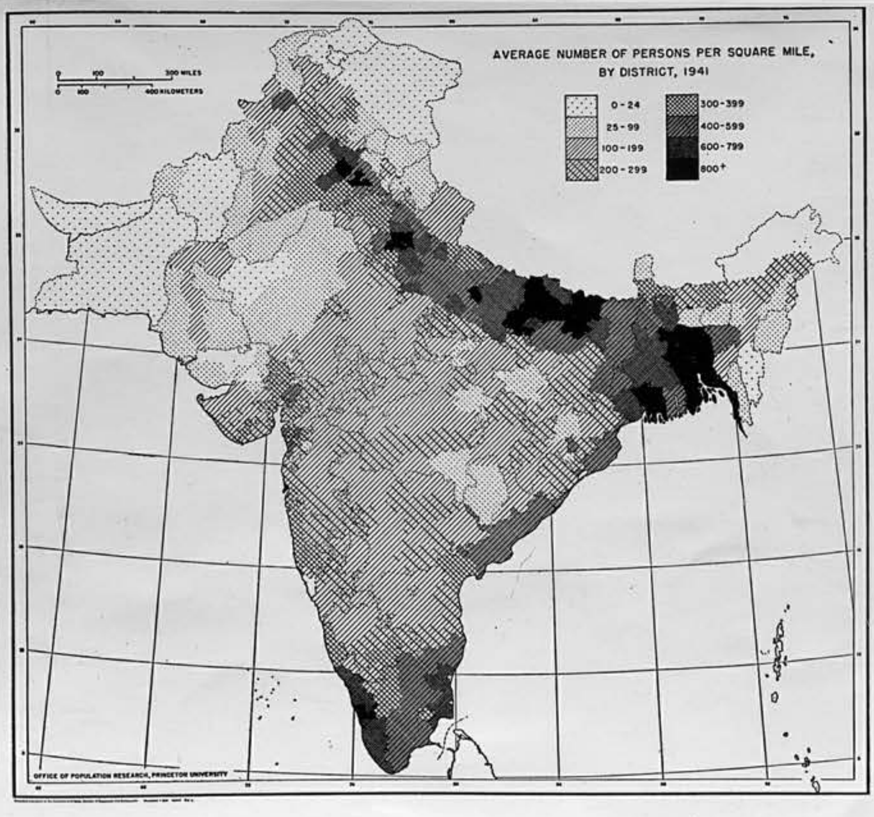
14


MUSLIMS
PER CENT OF TOTAL POPULATION
1941
PER CENT
0.0—10.0
10.1—25.0
25.1—50.0
50.1—75.0
75.1—100.0
SCALE
0
400

rapidly increasing number of city-dwellers in the great ports and commercial cities, ancient cultural and religious centres, capitals and administrative cities, and hundreds of small market and administrative towns. There are notable industrial concentrations on the Damodar coalfield of West Bengal and East-central Bihar, on the iron-fields of Singhbhum, on Hooghlyside with its jute mills and very diverse congeries of industries, and around the textile mills of Bombay, Ahmedabad (about 250 miles north of Bombay, in Gujarat), and in many smaller but growing 'up-country' textile centres.

The distribution of the main religions is shown in figures 13 to 14, as it was at the end of the period under review. (This distribution has of course since been greatly altered by the great movements of population following Partition). While many features of the way of life are common to most of the people, other features, some of which have been mentioned, differ between different religious communities.

A map of density of population is reproduced as figure 15. The densest tracts are in the East Bengal delta, Hooghlyside, the lower-middle Ganges basin, round Delhi, Bombay, Amritsar-Lahore, and Cochin. There is almost continuous dense settlement from Travancore and Cochin round the South and South-east of the peninsula, in the eastern deltas, and then from the Ganges-Brahma-putra delta in a broad belt to the Jumna river, after which a narrower belt follows the hill-foot of Punjab. At the other end of the scale are the empty patches of the Thar Desert and semi-desert, the rainy forests of the Western Ghats (not shown on this


AVERAGE NUMBER OF PERSONS PER SQUARE MILE,
BY DISTRICT, 1941
0 100 300 MILES
0 100 400 KILOMETERS
0 - 24
25 - 99
100 - 199
200 - 299
300 - 399
400 - 599
600 - 799
800+
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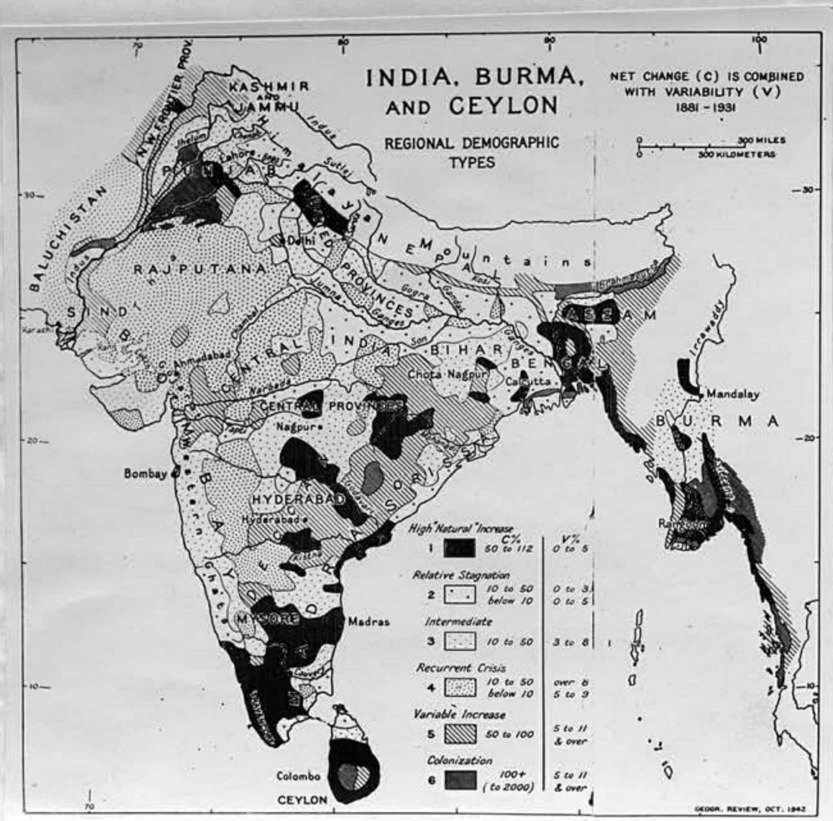
15.

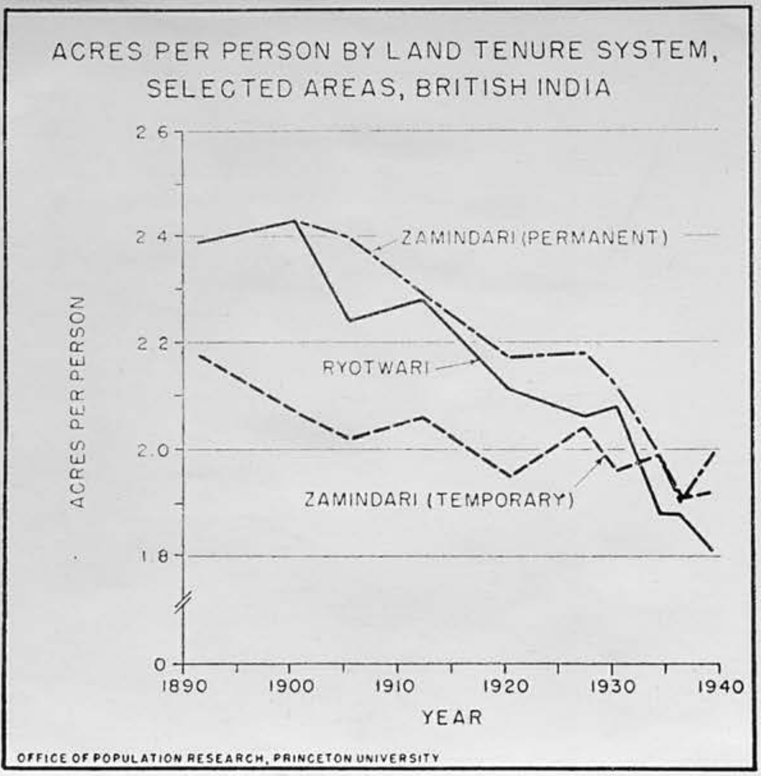


INDIA, BURMA, AND CEYLON
REGIONAL DEMOGRAPHIC TYPES
NET CHANGE (C) IS COMBINED WITH VARIABILITY (V) 1881 - 1931
300 MILES
300 KILOMETERS
High "Natural" Increase
C%
V%
1 50 to 112 0 to 5
Relative Stagnation
2 10 to 50 below 10 0 to 3 0 to 5
Intermediate
3 10 to 50 3 to 8
Recurrent Crisis
4 10 to 50 below 10 over 8 5 to 9
Variable Increase
5 50 to 100 5 to 11 & over
Colonization
6 100+ (to 2000) 5 to 11 & over
KASHMIR AND JAMMU
N.W. FRONTIER PROV.
BALUCHISTAN
PUNJAB
RAJPUTANA
SIND
Delhi
Lahore
UNITED PROVINCES
CENTRAL INDIA
BIHAR
BENGAL
ASSAM
Chota Nagpur
Calcutta
CENTRAL PROVINCES
Nagpur
Ahmedabad
Bombay
HYDERABAD
Hyderabad
ORISSA
Madras
MYSORE
Colombo
CEYLON
BURMA
Mandalay
Rangoon
Karachi
Himalaya Mountains
Western Ghats
GEOGR. REVIEW, OCT. 1942

16.

map), the several forested refuges of primitive aboriginal folk in the eastern Plateau, the Khasi plateau in the North-east, and the northern mountain ranges. The association of the densest populations with the rice-lands is particularly clear.

The net regional changes in population, increase or decrease have been studied and mapped along with the variability in change, and both have been related not only to the physical and cultural environment but also to the differing attitudes of mind of groups of people in different 'demographic regions' (Geddes, 1942, and 1947 whose map is reproduced as figure 16). Thus 'high natural increase' is found in the active delta of East Bengal but not on the islands of old alluvium therein; it is found in the zone of rice, manioc and coconuts in Travancore and Cochin, and in much of the 'tank' country of the South-east. 'Stagnation', on the other hand, is found in the malarious dying delta of West Bengal, and much of the Ganges basin. 'Recurrent crisis' caused by famine or epidemic, is found in the areas of instability already mentioned in Central India, and in contrast the great increase of 'colonisation' is seen in the canal colonies of the Punjab, and in the very different tall grasslands of the Assam valley. This last work and the several papers based on it, comprise a synthesis of great value, and amongst other things perhaps the only attempt to examine the vitality and outlook and something of the general health of whole communities in the


ACRES PER PERSON BY LAND TENURE SYSTEM, SELECTED AREAS, BRITISH INDIA
ZAMINDARI (PERMANENT)
RYOTWARI
ZAMINDARI (TEMPORARY)
ACRES PER PERSON
2.6
2.4
2.2
2.0
1.8
0
1890
1900
1910
1920
1930
1940
YEAR
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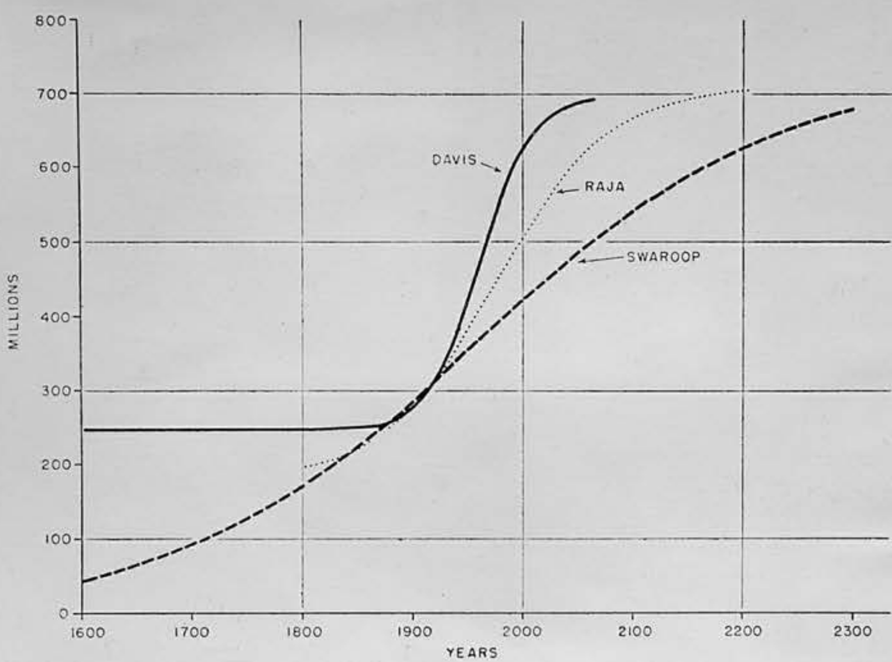
17.

LOGISTIC CURVES FITTED TO POPULATION DATA, INDIA



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18.

differing regions of the sub-continent. It is easy to lose sight of this broad point of view in dealing with a particular problem, and the map and these brief comments are given here in the hope that they and the other foregoing maps may be useful for reference throughout the reading of the ensuing chapters.

From the demographer's point of view, Kingsley Davis has recently given us a work of great value in looking at the population of India and Pakistan without taking count of regional differences therein. Two of the most revealing graphs are reproduced as figures 17 and 18. The former draws attention to the continuously decreasing acreage of land per person, under several types of land tenure. The latter uses knowledge of past population trends in order to make a long-term forecast of future trends; it is significant that the earliest estimate of when the population curve may be expected to 'flatten out' - so far as existing factors are concerned - is in about a century from now.

To see things whole is the geographer's aim. But he may work on several scales. The preceding pages outline some of the main inter-actions and inter-relations as he sees them on a broad scale, looking at the whole sub-continent of Indo-Pakistan. The succeeding chapters are mainly devoted to cartographic analyses on a similar scale by which the writer hopes to add a little to our understanding of the sub-continent from the point of view of medical geography.

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1 Geddes' work has received remarkable corroboration in Hyatt Williams' 'A Psychiatric Study of Indian Soldiers in the Arakan' (1950). This final link between the other inter-relations studied by the geographer and the regional differences in men's minds both healthy and diseased, is clearly of great significance. It lies beyond the scope of this outline of the geographical setting and of the main part of the present study, but will be referred to again in the Conclusion.

CHAPTER 1.

Rationale and methods [1] Statistical and Cartographic

These maps were drawn because of the writer's initial wish to approach the subject with a general view of the sub-continent, showing the distribution in space of those indices of health and disease which have for many years been recorded in the Provincial Health Reports of the former British India. Along with this areal distribution of intensity of incidence of the phenomena, it seemed desirable to map also the variability of incidence over a suitable term of years. The period 1921 to 1940 was chosen as neither too short nor too long nor yet too long ago. Too short a period might fail to give a significant classification of districts, while too long a period might give too much weight to past phases of medical history - like the great plague epidemics on the one hand, or the formerly lower (or even less adequately recorded) incidence of respiratory disease. A recent period is desirable because the writer's interest lies in the medical geography of the present rather than in medical history, but the decade ending in 1950 is impossible to deal with in this way because of war-time gaps

1. Appendix C on Statistical Methods has kindly been written by Miss Elizabeth Gittus, in order to present a more technical account to the mathematically minded.

in the data. There are strong practical reasons for choosing a period beginning and ending at or very near the relatively firm ground of published census data. The 1951 census figures were not available when the bulk of the work was done, while at the other end of the period it was finally decided, not without doubts, to start in 1921 despite the disadvantage that the early years include the exceptionally heavy mortality and morbidity following the influenza pandemic of 1919 to 1921.

While the writer was turning these aims over in his mind, he read a paper by A.R. Sen, an Indian statistician, on "Vital Statistics in the U.P., a critical analysis of forty years' data". Sen had also been attracted by the problem of studying and correlating (but not by the use of cartographical technique) the average incidence of mortality from certain diseases and the variability therein from year to year. Sen used a method, briefly as follows:-

The mortality from the chief epidemic diseases, plague, cholera and smallpox, was averaged for each administrative District for the 40 years 1901-1940. The "variance" for the same period was then calculated by the recognised statistical technique.[1] He then used a statistical method aiming at a non-subjective triage to reveal which Districts were "high", "normal" and "low" in respect of (a) average mortality and (b) variability (or "variance") in mortality over the 40 years. The principle used assumed that the

1. See Appendix C for technical description.

average mortality from a disease would, like many biological phenomena, approximate to the theoretical "Gaussian" or "normal distribution" curve, if the number of Districts with various degrees of intensity of mortality were plotted on a graph. Similar principles were applied in the case of variability. If this assumption be correct, it can be calculated that at a certain selected degree of probability, say 19 to 1, all "normal" Districts will fall within a certain area of the curve, while those above these limits may be regarded as "high" and those below as "low".

The first statistical opinion which the writer obtained on Sen's method was favourable, and there began the long task of preparing the statistical raw material, i.e. getting it from the Health Reports scattered among several libraries into a shape suitable for statistical analysis and carrying out certain preliminary computations. This was done in respect of the following phenomena; births, deaths, infant mortality, and deaths from fevers, dysentery and diarrhoea, respiratory diseases, cholera, plague and smallpox. It is widely acknowledged that all the figures are inaccurate, and that the least inaccurate are the striking and easily recognised epidemic diseases, cholera, plague and smallpox. Thus Sen, for instance dealt only with these three diseases. At the same time, the proportion of the mortality and of the subcontinent's terrible burden of morbidity, which these three diseases account for, is relatively small. It was resolved, therefore, to attempt the statistical analysis for all the figures reported for the period 1921 to 1940 in the Provincial Health Reports and the author believes they have some value as now presented. Other small but not uninteresting items - rabies, male and female suicides, wounds and accidents have not been dealt with, leaving until later the essential task of trying to corroborate any findings therefrom by samples from areas where more accurate data may be available.

As well as the absolute figures, the Provincial Health Reports quote rates per mille of population for the phenomena which they record. But with few exceptions, these rates are based on the population as recorded at the previous decennial Census. Each inter-censal year thus has its rates somewhat in error, normally increasing to a substantial amount in the ninth year. For this reason, a very simple graphical method was adopted in order to give an estimate of population for the inter-censal years, taking into consideration (a) the Census figure at the beginning of the decennium (b) the Census figure at the end of the decennium and (c) the recorded annual excess of births over deaths, or vice versa, according to the Provincial Health Reports. This crude method, described in Appendix D, was considered adequate in view of the known inaccuracies in the data, the great mass of material to be handled, and the desire for speed in these preliminary operations. This was done for every district in British India, and using these estimates, a fresh calculation of the rate per mille of population was worked out for each District for the period 1921 to 1940, in respect of the nine phenomena already listed. This work, involving some 50,000 simple calculations, was done mostly by the writer and his wife jointly but with some other help noted in the Preface; this task took several months to complete, even using a slide-rule which gave great speed and sufficient accuracy in view of the nature of the data.

At this stage, a further statistical opinion was sought as to how best to handle this mass of raw or, at best, partially sifted material; this was generously given by H. Silcock and Miss E. Gittus, the statisticians of the Social Science Department of the University of Liverpool. They advised that to minimise the heavy labour of computation involved, in statistical analysis, the data should be transferred to Hollerith punch-cards. This was done under Miss Gittus' supervision, and with generous financial help from the Carnegie Trust for the Universities of Scotland. Silcock and Gittus had by now had the nature of the problem before them for several weeks, and after careful thought they advised that Sen's apparently promising method of identifying which Districts were "high", "normal" and "low" for any particular phenomenon should not after all be followed through in its entirety.

Their critical scrutiny of Sen's method suggests that while his classification of Districts is certainly not subjective, it may well have drawbacks serious enough to outweigh this advantage - viz. (a) it is in fact quite arbitrary, (b) the "high" and "low" districts by definition fall into these categories by chance, and the fact that this is a known and calculated chance of 19 to 1 does not imply that the classification has necessarily any significance to the medical geography of India, and (c) the assumption that frequency distribution of the different rates per mille for the various phenomena examined approximates to a Gaussian curve is not in fact justified-several of these, for All-India, have been shown to be markedly "skew".

The mean incidence for the period was calculated, and dispersal diagrams constructed for each phenomenon. Then each District was classified as high, medium or low. Only a few diagrams show any pronounced grouping, and this classification is therefore generally arbitrary, the upper quartile being high, and the lower quartile low.

The variability was calculated by the usual statistical method of the sums of squares, or by a labour-saving approximation suitable to such crude data, evolved by Miss E. Gittus.[1] The variability for each phenomenon was also plotted on a dispersal diagram, and each District similarly classified as high, medium or low.

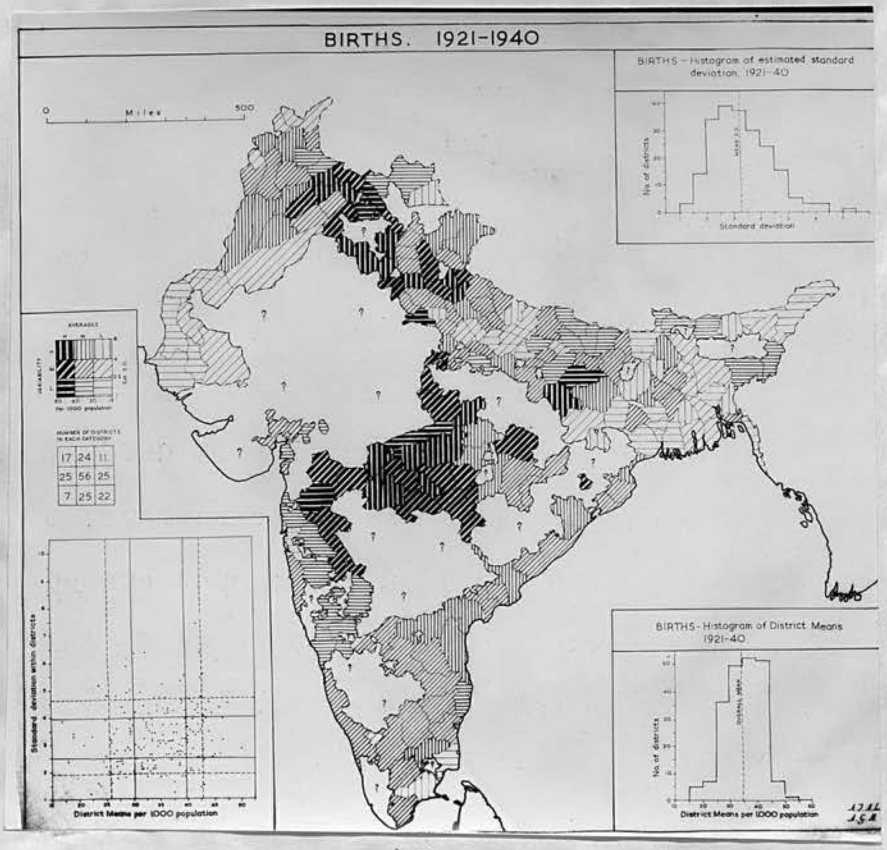
The results so far were now plotted on maps, each District

1 Miss Gittus has contributed an account of this work, see Appendix C.

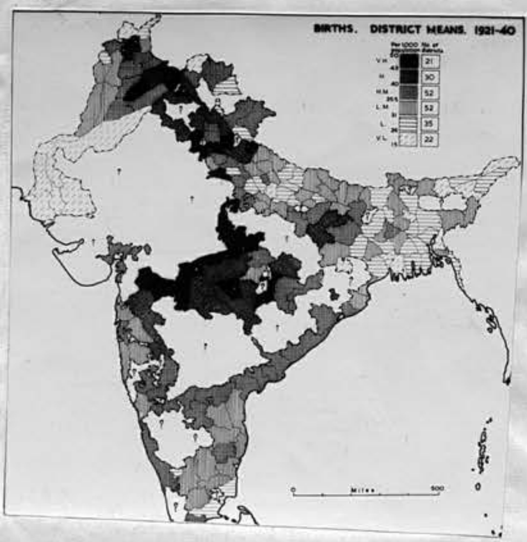
indicating its mean incidence and its variability, thus classified, giving nine combinations, as seen on figures 19A etc . For each phenomenon, the District means 1921-40 and the variability, were plotted against each other in a correlati on diagram, District by District, and the arbitrary dividing lines were shown so that their significance may be assessed. A strong linear trend, showing correlation of high means with high variability, occurs in several cases. Histograms were also drawn on each map, for means and for variability, to show the "shape" of the distribution from this point of view; this affords further help in assessing the relations of the Districts classified as low or high to the whole body of data. The key shows the numerical values attached to high, medium and low in the particular map, and also shows the numbers of Districts falling within each of the nine categories.

The distribution diagrams were then re-examined, and the data re-classified, generally with additional categories for very high and very low (the top and bottom ten per cent of the Districts respectively), or with a high medium and low medium category, in which the division is made at approximately the median value. The numerical values and the numbers of Districts in each category are similarly shown in the key.

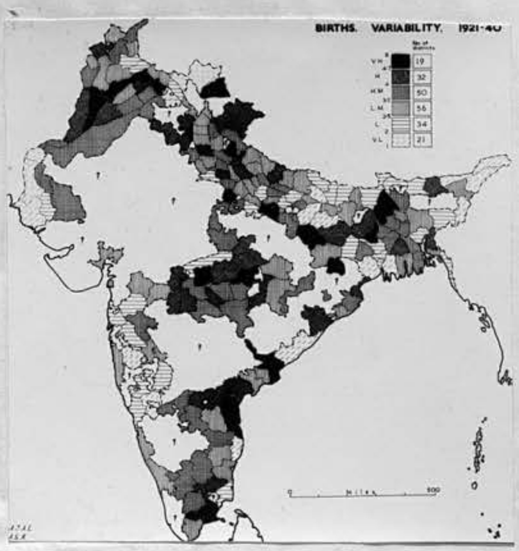
An analysis of these maps will now be made, and broad correlations attempted.


BIRTHS. 1921-1940
BIRTHS – Histogram of estimated standard deviation, 1921–40
No. of districts
Standard deviation
0 Miles 500
17 24 11
25 56 25
7 25 22
Standard deviation within districts
District Means per 1000 population
BIRTHS - Histogram of District Means 1921-40
No. of districts
District Means per 1000 population

19A


BIRTHS. DISTRICT MEANS. 1921-40
21
30
52
52
35
22
0 Miles 500

19 B


BIRTHS. VARIABILITY. 1921-40
19
32
50
56
34
21
0 Miles 500

19C.

CHAPTER 2.

Births.

The combined map, showing both intensity and variability of incidence of births, is figure 19A.

Much of Bengal shows as low mean with low variability in the western, dying delta, which accords well with Geddes' picture of population stagnation, whereas most of the eastern, active delta has medium variability (Geddes 1942). One must suspect under registration in East Bengal, which Censuses show to have a high rate of increase, due to natural increase. Eastern Bihar including plateau, flood-plain and hill-foot Districts has also low means, but with low, medium and high variability. Central United Provinces has a group of low means with mostly medium variability; a similar though not identical group shows as light compared with neighbouring groups of Districts in western and eastern United Provinces in nearly all the maps - cholera is a partial exception. These lighter recorded means may be due in part to under-registration, but may be due rather to a change in the landforms/climate complex from incised detrital cones to the beginnings of inundable flood-plains and hill-foot terai, but not yet with frequently flushed water-courses. The groups of Districts in Sind and Assam with low means and medium and low variability are generally believed to appear so because of under-registration (All India Health Report 1938 V.I p. 7). The histogram of means shows such a remarkable drop to the low Districts as to support this.

Apart from several scattered District, the only other low group comprises the deltaic Districts of Tanjore and Ramnad in the south-east of Madras, with low and high variability respectively.

At the other end of the scale, there is a great black patch of high birth rates in the plateau Districts of eastern Bombay, Central Provinces, and possibly thrusting east across the Eastern States to the last gently sloping pavement of plateau in south-west Bihar, and again leap-frogging northwards round the large blank area of Rajputana to western United Provinces and eastern Punjab. Variability is mostly medium and high. This India of high birth rates is largely also the India of millet and wheat grown in uncertain rainfall, and in parts on rapidly eroding soil, the India of periodic famine and near-famine, partly relieved by irrigation in the Punjab and United Provinces. In part, it has paradoxically shown decrease of population in recent decades. The central area in particular appears on several of these maps as a distinctive region. Except in the north-west, there is a suggestion of an inverse relationship with density of population.

That half of the total Districts which the writer's classification of means has called medium has a particularly wide sweep in the peninsula, including plateau country and some deltas; there is mainly medium variability.

Some further information may be obtained by turning to the map of variability alone (figure 19c).

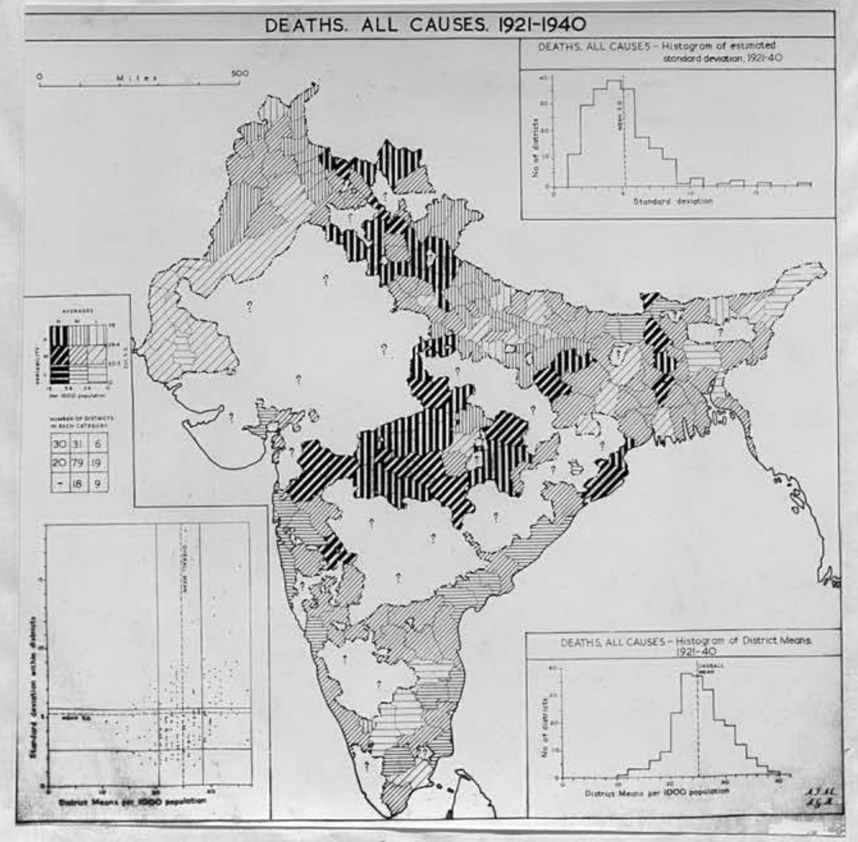
The Districts of low and very low variability include parts of the western Bengal delta, the extreme east of Bengal, most of Assam, and extending thence westwards along the hill-foot to include much of northern Bihar and some Districts south of the Ganges. Some hill and hill-foot Districts of Punjab are in this grade, and much of Sind. Much of Bombay is also included, mostly plateau Districts, and scattered Districts along the eastern seaboard, some being deltaic.

Towards the upper end of the scale, it is worth while grouping high medium, high and very high Districts - i.e. all those above the approximate median value. Apart from the distributions already noticed in the combined map, the denser groupings are worth noting in south-west Punjab, in eastern Madras away from the deltas, and in a broad belt running north-west to south-east across Bengal following the main distributary of the Ganges. Such fluctuations in India are indicative of markedly varying conditions of health and prosperity.

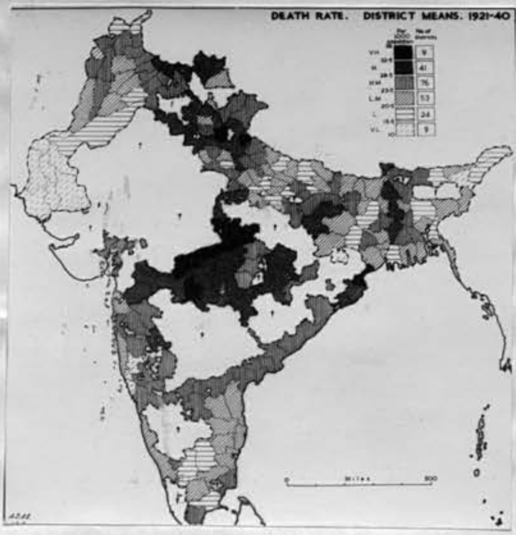
<u>Discussion.</u>

The high birth rates are associated above all with the lands of wheat and millet, of variable rains and harvests, and of epidemic conditions especially of malaria. In the rice-lands constantly low birth rates (by Indian standards) are associated with hyperendemic malaria, especially in deltas. There are low but variable rates in the relatively malaria-free 'active delta'.

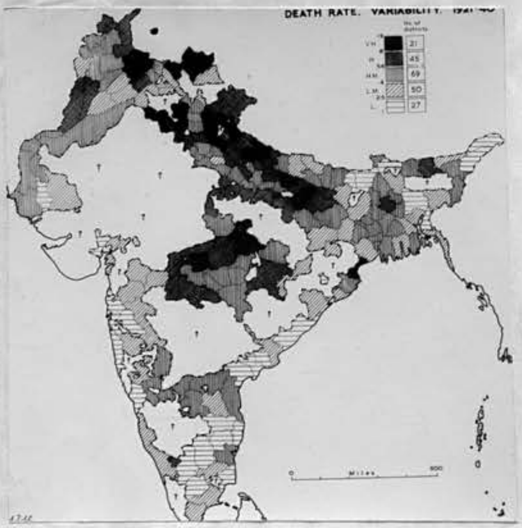
And similar rates are found in the area of the middle Ganges growing rice in the flood-plains and the terai but generally rather marginal climatically to the needs of rice, and dependent largely on maize. The rice-and-millet lands of the south including the 'tank' country and the rice-and-tapioca lands of the south-west are striking for their tendency to high medium birth rates, which are rather variable; malarial conditions are from moderate to high endemicity in much of the coastal belt to moderately epidemic conditions in the drier inland parts of the plateau, with smaller areas of more extreme conditions.


DEATHS. ALL CAUSES. 1921-1940
DEATHS, ALL CAUSES – Histogram of estimated standard deviation, 1921-40
No. of districts
Standard deviation
0
Miles
500
AVERAGES
VARIABILITY
per 1000 population
NUMBER OF DISTRICTS IN EACH CATEGORY
30 31 6
20 79 19
– 18 9
Standard deviation within districts
OVERALL MEAN
District Means per 1000 population
DEATHS, ALL CAUSES – Histogram of District Means, 1921-40
OVERALL MEAN
No. of districts
District Means per 1000 population

20 A


DEATH RATE. DISTRICT MEANS. 1921-40
9
41
76
53
24
9
Miles
500

20 B


DEATH RATE. VARIABILITY. 1921-40
21
45
69
50
27
Miles
500

20 C.

CHAPTER 3.

Deaths.

The combined map for deaths is figure 20,A,. Some resemblance to the map of births is to be expected, since about a quarter of the total deaths consists of infants under one year. A similar black mass is to be seen in the centre of the Indian diamond, stretching a tentacle northwards to the hill District of Kangra in Punjab, and north-eastwards to western Bihar as before. The Orissa delta shows as high also, and there is a north to south belt in Bengal, from sub-Himalayan Darjeeling to deltaic Nadia. Variability is high or moderate.

Sind and Assam again show low rates, and under-registration is again a main factor. On this map parts of south-west Punjab are also low. Variability is mainly medium. Much less is low in Bengal and United Provinces, but the southern peninsula has more low Districts, including several on the plateau. Variability is mainly medium in western Bengal and United Provinces, and the deltaic District in the south, but is low on the southern plateau.

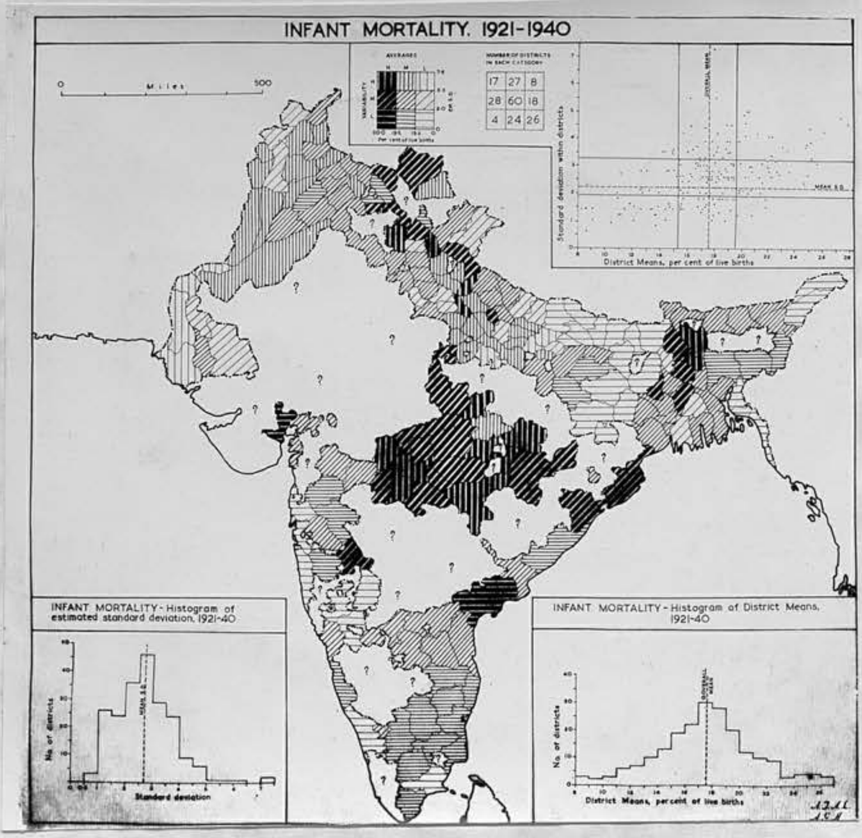
The means alone appear on figure 20B. Like several of it's type, it may serve to test the results derived from the combined map. The very high category draws attention to the Central Provinces again, to the Orissa delta, and to western United Provinces. But it may well be better to group high medium, high and very high, when the distribution already studied is confirmed.

It is notable that much of the plateau and of the eastern sea-board are high medium, in a belt contiguous to Hyderabad State to the south-west and south-east.

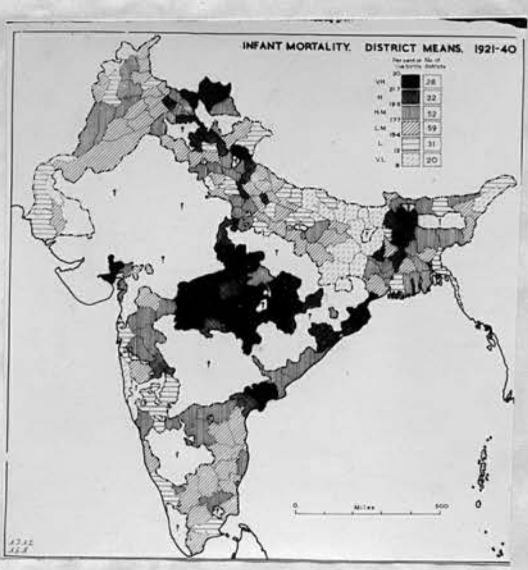
The map of variability alone is figure 20C. The grouping of Districts with high medium, high and very high rates shows a family resemblance to the distributions on the other maps of incidence and variability above the median value. The central group, however, begins farther east (excluding the Districts north-east of Bombay City), while very much more of the central Ganges plain is in this category, and central United Provinces shows as having quite variable death rates. Most of Sind and the north-west are in the higher group. Eastern Bihar appears as low or medium, but western Bengal shows a big group of high medium or high, stretching north to Darjeeling. Assam shows high in this map, and part of the Orissa delta is very high. Again, much of the plateau south of Hyderabad State is high medium, but most of Bombay province, coast and plateau alike, and much of the eastern sea-board, including the Tanjore and Godavari-Kistna deltas, appear as low.

Discussion.

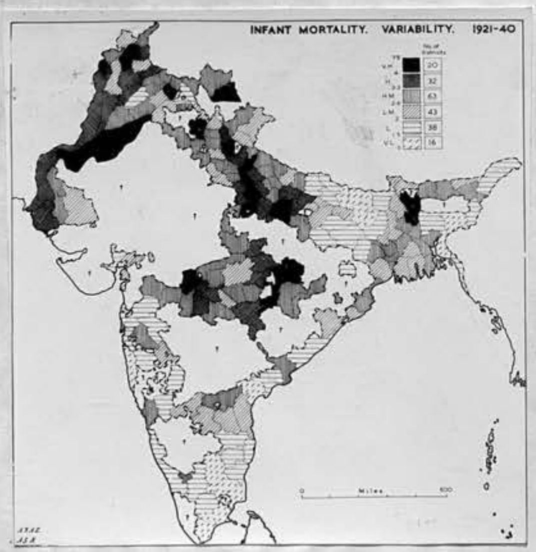
The important relation with the birth rate must again be mentioned. The death rate is high in a great area of rather scant and fickle rainfall, of epidemics and variable harvests of wheat and millet in middle India. It is high in the Orissa delta of rice lands and religious centres, of malaria, filariasis and cholera, and in certain other rice-lands, some in the Ganges flood-plain proper, and others not subject to sheet-floods but to rather heavy leaching rains. The hill- district of Kangra has also high death rates, associated with poor nutrition and general health in a quite pluviose area growing maize and potatoes in conditions of backwardness and overpopulation. The areas of low death rates one can at present only be associated with under-registrations, but the medium grades can reasonably be correlated with the rather more prosperous areas of cultivation whether of rice, wheat or millets. It is striking how the death rate appears as much more variable, on the whole, in the northern two-thirds of the sub-continent, even in those areas characterised by Geddes as 'stagnant' from the point of view of population change and variability. The age-incidence has not been investigated, but it may be that these variations are due to deaths of children at a time when a secondary infection such as measles is added to the severe infestation by malarial parasites characteristic of these areas (see p. 124).


INFANT MORTALITY. 1921-1940
Miles
INFANT MORTALITY - Histogram of estimated standard deviation, 1921-40
No. of districts
Standard deviation
INFANT MORTALITY - Histogram of District Means, 1921-40
No. of districts
District Means, per cent of live births
District Means, per cent of live births

21A.


INFANT MORTALITY. DISTRICT MEANS. 1921-40
Miles

21B


INFANT MORTALITY. VARIABILITY. 1921-40
Miles

21C.

CHAPTER 4.

Infant Mortality The combined map is figure 21A.

Again there is a natural family resemblance to the maps for births and for deaths, since about a quarter of the total deaths are of infants, and since about one-fifth of the babies born die in their first year, appearing within that period in the records of births and of infant mortality.

The heart of the Indian diamond is again black, but the black patch starts farther east, and notably on the boundary between Bombay and Central Provinces. And it includes even more of the Central Provinces themselves. The black tentacle reaching north again to Kangra in the Punjab hills keeps more to the hill-foot en route. It is remarkable that the famine Districts of Punjab are not included.[1] Medium variability predominates, and there is little high variability. Western Bihar does not come within this grade here, but the black area in Central Bengal is wider. The black patch over the Orissa delta extends south into the adjacent low-lying District of Ganjam, with medium variability, and it is on this map accompanied also by the Godavari-Kistna delta which, however, has the even more sinister combination of high

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1. Particularly valuable accounts of the famine of 1938-39-40 in Hissar and neighbouring Districts are given in the Reports of the Public Health Administration of the Punjab for 1939 and 1940 (Govt. Printing Press, Punjab, 1941 and 1942 respectively).

infant mortality with low variability. The isolated District in south-east Bombay is Sholapur, with medium variability, and it may be linked with Ahmedabad in Gujarat - again with low variability - in that both Districts contain growing cotton-manufacturing towns. Other scattered Districts with high variability are rather difficult to account for; Rangpur, for instance, just west of the Khasi hills, had one very high year - this coincided with a bad year for smallpox in that District, but even in an epidemic the number of smallpox sufferers would not account for such a big increase unless pregnant mothers have a peculiar liability to it, and it seems more likely that the high infant mortality was due to a high incidence of malaria.

The Districts with low means include much of North-West Frontier Province and Sind, where, in Muslim India, under-registration is believed to be an important factor, and also Assam, which again is suspiciously low. The histogram for the means does suggest that the very low Districts have an unnaturally wide disparity from the mass of the population for a biological phenomenon of this nature. The south-east fringe of Bengal has some Districts of low mean and low variability, and parts of the western delta are of low mean and medium variability (Calcutta is not included but is in the high category). Most of Bihar has low means with low variability, and this extends into eastern United Provinces, though with high variability. One can not but suspect at least some under-registration, since the eastern edge of this light patch corresponds so exactly with the boundary between Bengal and Bihar. Low means with low variability are found again along much of the western seaboard, parts of the western plateau, and Ramnad in south-east Madras.

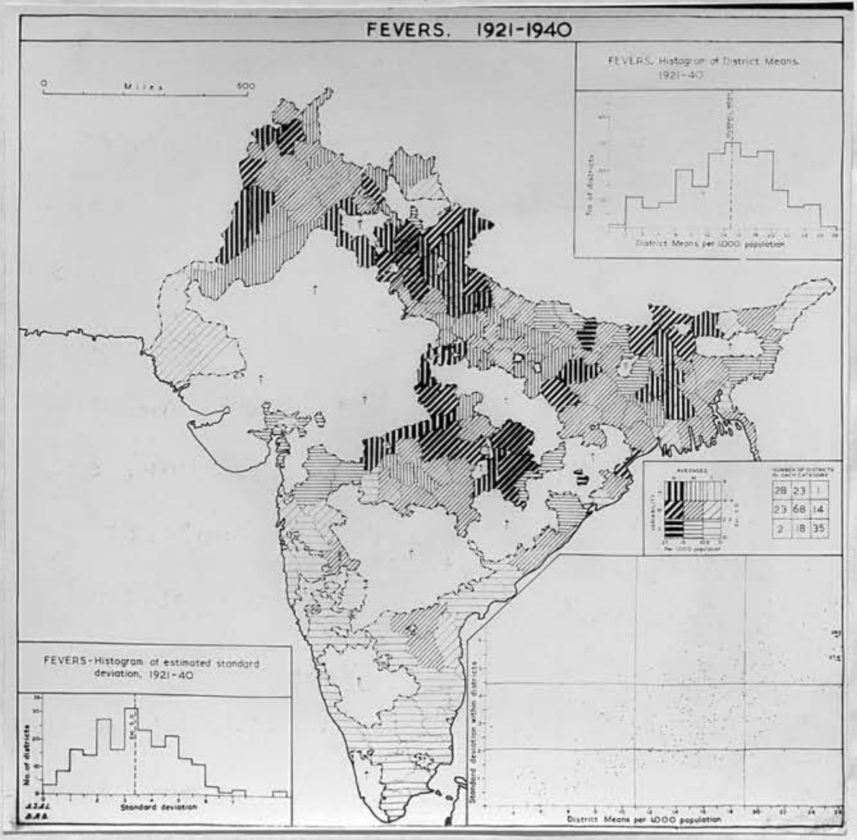
The map showing means alone is figure 21B. This shows up the central black patch as black indeed, with a great massing of the very high grade, while the light patch in Bihar and eastern United Provinces accounts for nearly all the very low grade in the whole sub-continent.

The variability mapped alone appears as figure 21C. Here some of the central Districts are revealed as having values very much lower than have been seen in previous maps, although the group is still sufficiently above the median value to appear as at least a dark patch, again extending north and north-west. South-west Punjab, North West Frontier Province and most of Sind appear as extremely variable. Variability above the median is found in western Assam and much of deltaic Bengal - the very high District of Rangpur has already been mentioned - but the low medium area should be noted east and west of but not including Calcutta. Bihar and eastern United Provinces again appear as low and very low, but there is much more low variability than low means along the south-eastern coastal lands and again on the western seaboard.

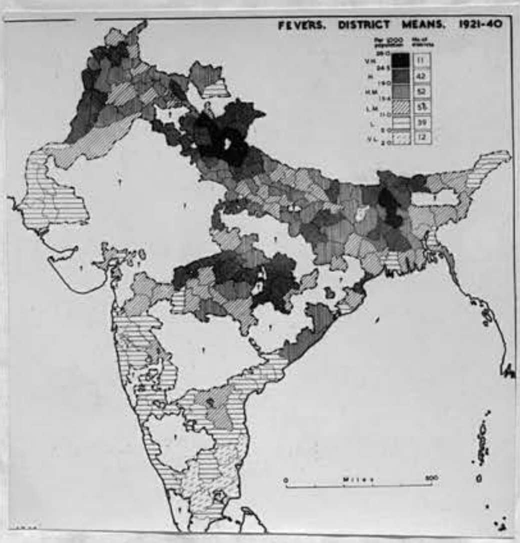
Discussion.

The unsatisfactory conditions of environmental hygiene are, of course, in themselves of fundamental importance as a factor in the death rates in childbirth or near to it, both of mothers and children; this is so widespread among the poorer folk all over the sub-continent as to be almost a common factor. If there is a differential influence it is that the poor of even a city slum have a somewhat better prospect of going to a maternity hospital than have the women of rural areas. These are factors which India shares with many other countries. Unfortunately the attitude of those who are both backward and orthodox - which means the majority- among the believers in the main religions, makes the situation even worse, and again especially in rural areas. In the case of the Muslims there is the darkness and secrecy of purdah, and in the case of the Hindus the ritual uncleanliness of childbirth and the very strong tradition of the employment of hereditary midwives from among the poor and ignorant untouchables, whose methods are responsible for a hugh annual total of suffering and loss of life.

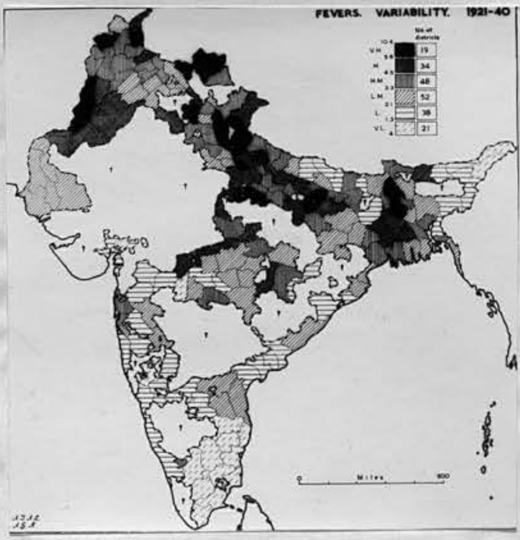
Under these circumstances, a peculiar and baleful significance is attached to a high incidence of premature births. There are many malpresentations, which might right themselves if they went to the full term of pregnancy. In the hands of the ignorant and untrained attendant, many of the premature babies die or are mutilated and many die soon after birth because the special care needed can not be given by the unskilled nurse nor by a mother ill after the birth and also frequently attacked by malaria at her time of weakness. The direct and indirect effect of prematurity are undoubtedly concerned in a very high proportion of the high infant mortality rates seen in India, and much of this is probably due to malaria (see Appendix A). If this be so, the high and variable rates of the centre and north, shown on the maps, are probably linked with malaria, mainly epidemic in character although endemic along the northern hill-foot and in forested hill tracts of Central India. The poor and backward hill-district of Kangra, mentioned in chapter 3, again shows high rates. There are high rates in certain deltaic areas, while the deltas in general tend to have rather low variability, in keeping with the endemic malaria there. Some of the cotton manufacturing areas also show high infant mortality rates. The probable importance of epidemic malaria is supported by the map of variability alone, where the higher values are strikingly concentrated in the centre and north-west of the sub-continent. A factor in the higher means in the north-western quadrant of India may be the higher incidence of osteomalacia there - that is, adult rickets due to vitamin D deficiency, occurring more in women and especially obvious in pregnant women and of these, particularly Muslim women who observe strict purdah, and who therefore miss the beneficient effects of the sunshine available out-of-doors (Wilson 1929-30). Syphilis is undoubtedly an important element in the infant mortality and especially in the still-births, about which data are still quite fragmentary, but it is difficult to say whether it is of equal importance everywhere or varies from town to country or region to region (Thomson 1931). One very widespread cause of infantile deaths is anaemia caused by the long period of dependence on suckling, up to two years or more; milk is a poor source of iron, while the baby at birth is supplied with reserves of iron sufficient only for about six months. (Passmore 1948).


FEVERS. 1921-1940
0
Miles
500
FEVERS. Histogram of District Means.
1921-40
No. of districts
District Means per 1,000 population
AVERAGES
VARIABILITY
Per 1,000 population
28 23 1
23 68 14
2 18 35
FEVERS-Histogram of estimated standard deviation, 1921-40
No. of districts
Standard deviation
Standard deviation within districts
District Means per 1,000 population

22 A


FEVERS. DISTRICT MEANS. 1921-40
Per 1,000 population
No. of districts
V.H.
H.
H.M.
L.M.
L.
V.L.
11
42
52
55
39
12
0
Miles
500

22 B


FEVERS. VARIABILITY. 1921-40
No. of districts
V.H.
H.
H.M.
L.M.
L.
V.L.
19
34
48
52
38
21
0
Miles
500

22C

CHAPTER 5.

Fevers

In the maps based on the statistics for 'fevers' in the Provincial health reports, once more a family resemblance is to be found; one would doubtless expect this a priori because of the dominant importance of one febrile illness, malaria, as a public health problem in India. The value of the present and other manipulations of these particular figures is, however, sadly reduced because the very title admits defeat in the attempt to ascertain the exact cause of death, and invites the use of this category as a 'catch-all' repository, at least as much as 'all other causes'. Each year over half the total deaths are classed as fevers, and while about one third of these are often taken as due to malaria, the proportion is in fact very variable from region to region.

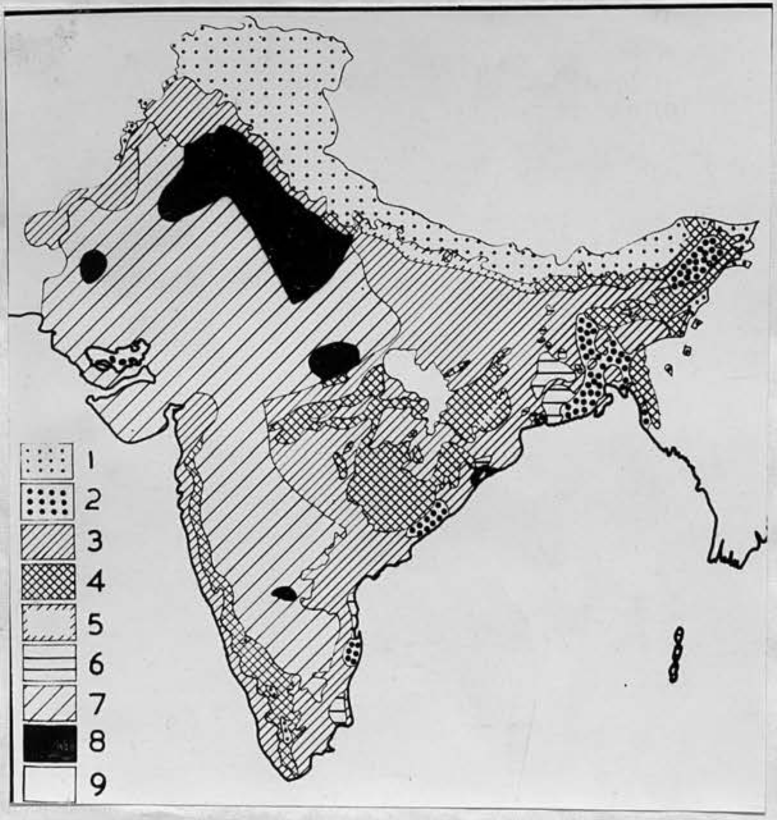
The combined map for fevers is presented as figure 22A. The central black patch is again present, but comprises mostly the north and north-east of Central Provinces. It once more stretches north, but this time to a much larger and almost dominant black mass in western United Provinces and eastern Punjab. After a break, this reappears in North West Frontier Province. The tentacle reaching into western Bihar is present, both on the northern slopes of the plateau and in the terai country on the north, whence it continues east into Bengal, and then leaves the hill-foot, to form a north to south belt comparable to that seen in the map of deaths from all causes. The variability is medium and high, with the latter dominant in the Upper Ganges plain and the north west, and again in the north to south belt just described. Only the northern fringe of the Orissa delta appears as high; this District has medium variability.

Among the low means, there appears much of Sind, with medium variability, but only the eastern tip of Assam, with low variability. There is a striking uniformity about the greater and southern part of the peninsula, plateau, coastal plain and delta alike having mostly low means and low variability.

The area of medium means and mostly medium variability also, fills in most of the interstices in all the northern two-thirds of the sub-continent, including areas of plateau, of flood-plain, of incised detrital cones and of hill-foot terai.

The means are mapped alone as figure 22B. This map serves to focus attention on the dominant very high group in western United Provinces and eastern Punjab, and on the smaller group of similar intensity in north central Bengal, and again on the lesser intensity of the central group compared with other maps studied. The very low group of the south east peninsula is almost equally striking.

All these features are seen to be repeated in the map of variability alone, figure 22C. This shows that the highest recorded death rates from fevers are associated with epidemic conditions rather than with severe endemicity, but it does not of course throw any light on the enormous drag on efficiency caused by morbidity in



23 Malaria map, 1940.....

Figure 23 - Malaria Map of India

KEY

Areas above 5000 feet (non-malarious)

Known healthy plains (spleen rate under 10 per cent)

Moderate to high endemicity of more or less static character, the intensity depending on local surroundings, seasonal variations moderate, fulminant epidemics unknown

Hyper-endemicity of jungly hill tracts and terai-land

Probable hyper-endemic hill areas

Hyper-endemicity other than that of hill tracts

Variable endemicity associated with dry tracts. Usually showing autumnal rise in fever incidence (potential epidemic areas), spleen rate low except for years follow ing epidemics or in special local circumstances; much affected by conditions of irrigation.

Known areas subject to fulminant epidemic (diluvial) malaria. Spleen rate dependent on occurrence of epidemics, high during and immediately after such, slowly falling to low rates in course of half-a-decade or so.

Unsurveyed.

Christophers & Sinton 1926
Malaria Survey of India 1940

te In view of the special importance of this work, a note on the map by Christophers and Sinton, and also Hehir's description of malaria in its regional aspect, are given in an annexure to Appendix A, pp. 102-

endemic areas under Indian conditions. Moreover these maps, like all this series, should be interpreted with the map of density of population in mind.

Discussion

In the case of fevers, it is desirable to compare these maps with a black-and-white map drawn from a recent member of the series of promptly amended and beautifully coloured malaria maps of the Malaria Survey of India, based on work originally by Christophers and Sinton, and ante-dating the survey by some years. (figure 23).

The northern and north-western fringe of the central black area corresponds with the variable endemicity and known epidemic areas north-west of Jubbulpore on the Malaria map; the rest of the central patch, with medium variability, corresponds with the area of moderate to high endemicity with belts (on topographic ridges) of hyperendemicity of jungly hill tracts.

The black patch in western United provinces and eastern Punjab with mainly high variability, corresponds well with the great stretch liable to fulminant diluvial epidemics, and the Bengal area approximates to the hyperendemicity of terai areas, along with some hyperendemicity other than hill tracts which here is on the old alluvium and on the dying western delta. The District of 24-Parganas, however, south-east of Calcutta, shows as surprisingly low on the present writer's map.

The areas mapped as relatively malaria-free, being flushed by ample flöod-water (and also relatively prosperous because of the renewal of silt, and therefore with better nutrition), appear often as high medium or sometimes even high, in the map of means, and often with high medium variability also. This is suggestive of periodic invasion by epidemic malaria, which indeed seems to have eroded these areas on the Malaria map a good deal since Christophers and Sinton first delimited them.

The peninsular areas which appear as relatively light on the present writer's map, are shown as malaria-free only round Madras City; elsewhere they cover country regarded as hyper-endemic, partly deltaic and partly in hilly jungly country, and also tracts of moderate to high endemicity without fulminant epidemics in areas of moderately high rainfall, tracts of moderate to high endemicity <u>with</u> rise after rains (potential epidemic areas) in conditions of lower <u>average</u> rainfall, and finally areas known to suffer from fulminant epidemics after the occasional wet year in the normally dry plateau area around Bellary.

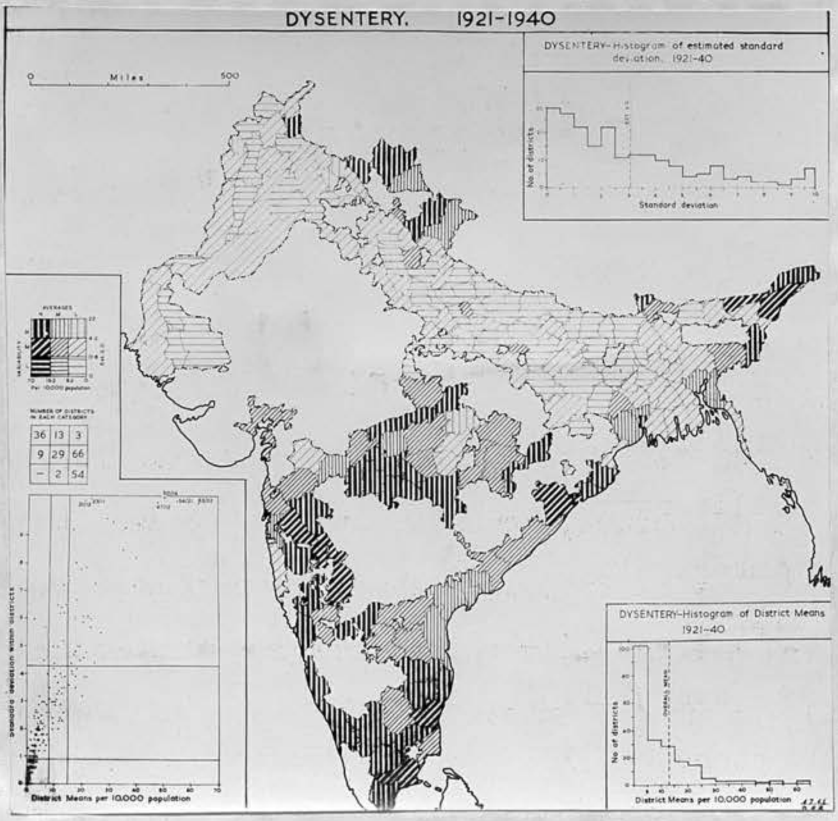
The malaria map certainly does show the greatest areas of severe malaria as occurring in the north, at both extremes of periodicity, the hyper-endemic and the fulminant epidemic types. But it appears that in addition, the present fevers map is weighted in that the northern areas, say north of Hyderabad State, will bear much the greatest burden of fevers other than malaria - pneumonia in the cool season, tuberculosis (often recorded as 'fever'), relapsing fever in the north-west and kala-azar in the north-east (both of these fortunately now controllable) and no doubt some misclassified plague in the centre and north-west also. The better nutrition and physique of the wheat and millet eaters in the North-West fails to protect them from this high mortality from malaria and other fevers, compared with the folk of Southern India with their poor rice and millet diets.

This malaria map of India and some of the medical literature concerning that disease are fairly systematically discussed in Appendix A, which shows the wide range of inter-actions which may ultimately prove relevant to a study of this kind. Meantime a much broader and more selective discussion will be attempted.

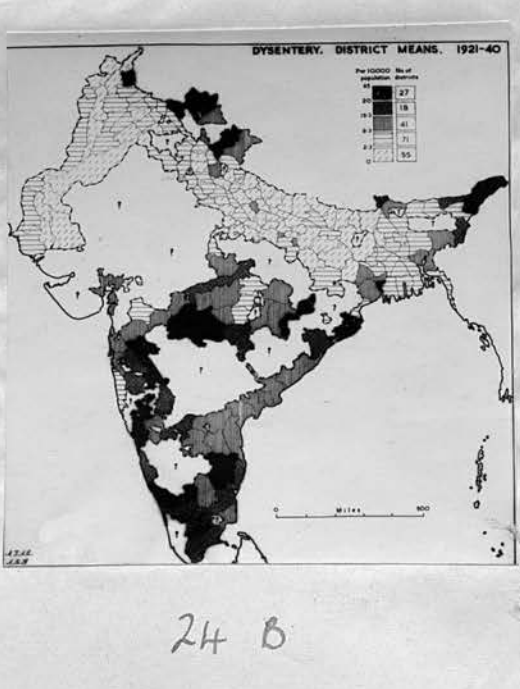
From the point of view of climate, and considering temperature first, it may be claimed that the division of the subcontinent in figure 7 into tropical and continental India has some significance from this point of view, although given time an ad hoc map more accurate for the present purpose could doubtless be drawn. Stamp's continental India approximates to the area in which the night-temperatures under 60°F in the cool months inhibit the activities of mosquitoes. From the point of view of humidity and rainfall, the mean annual isohyet of 40 inches - the approximate boundary of rice cultivation without irrigation - is of significance to the geography of malaria in both continental and tropical India; it is an approximation to the endemic areas, that is to the areas in which, within continental India, malaria will be considerable every autumn especially, and within tropical India will be present annually after heavy rainfall at any time of the year. Within the area of over 40 inches of mean annual rainfall, the areas of heaviest rainfall are by no means invariably the most malarious. There is indeed high endemicity in forested hill tracts of the foothills of the eastern Himalaya, of the Burma border country, and of the Western Ghats and various other tracts in the peninsula. But Malabar, for instance is not one of the most malarious areas. The active eastern delta of Bengal is notably free from malaria, although sheet floods from the rivers flushing the waterways and giving fresh silt to the fields, rather than local rainfall alone, are of paramount importance in the complex of human and anopheline ecology that maintains there. One must also look beyond the useful but often obscuring device of the climatic mean and the appropriate isopleth map, to variations in the rainfall from one year to another. In the drier, epidemic areas, the years of heavy incidence of malaria follow heavy rains (which in turn may have followed years of low rainfall and lean harvests), whereas more pluviose areas may suffer quite exceptionally as a result of abnormally stagnant water-courses in an exceptionally dry year.

Even the barest outline of the type of water preferred for breeding by the main vectors of malaria in India requires references to the table on page 108 ; but in a sub-continent whose people depend so largely on rice-growing and on irrigation, it is important to stress the importance of weedy and ill-maintained tanks and water-channels, and areas of water-logging from seepage and leakage from irrigation canals. And the borrow-pit should be mentioned; the borrow pits resulting from the building of houses may in extreme cases be difficult to remove without pulling the houses down to give the necessary material, but more often the obstacle in the way of their removal lies in the extreme attachment that the people have formed to the use of the resultant pool for other purposes. The brackish water of hollow deltaic islands reclaimed for agriculture and ponded up until it can be discharged at low tide, breeds its own important vector. Even apart from climate, the high water-table and other conditions of deltas and flood-plains are exceptionally friendly towards mosquito larvae in the eastern half of the northern plain (with the exception noted in East Bengal), and on the deltas and coastal plains around the peninsula. In these areas, as it were, land-forms climate and hydrography conspire together to favour malaria, and in many parts poor social and economic conditions are also at work. Even outside these pluviose areas, however, are other areas where water-bodies suitable for anopheline breeding are constantly present-the ribbons of flood-plains, the hill-foot belt with its high water-table, and the artificial conditions favouring malaria which need not but do in fact often accompany irrigation schemes great and small; all these may be considered as in some sense extensions of the conditions of delta or flood-plain, reaching like fingers into the area of less and more variable rainfall, bearing more endemic belts into the India of epidemic malaria.

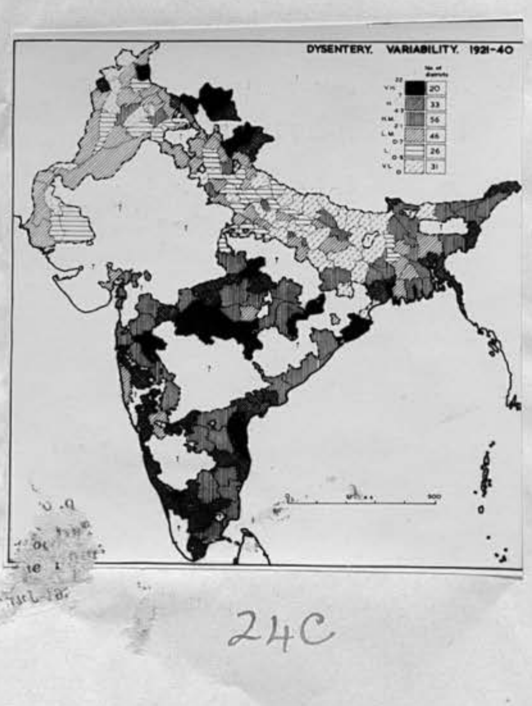
No one who is sufficiently interested in the subject to read these pages is likely to be ignorant of the vicious circle in which malaria is involved, along with poverty, mal-nutrition, ignorance and over-population in relation to the resources of the land. It has long been felt that better education is necessary for any lasting victory over malaria; but it is impossible to educate a malarious child. Better nutrition would increase resistance; but a malarious farmer can not cultivate efficiently, and so nutrition suffers. Of the more hopeful aspects, two may be mentioned - the very local nature of the malaria problem, except during an actual epidemic, and the fact that the main vectors of India are domestic - i.e. they bite their victims mainly indoors (especially by night). The residual insecticides have now given man the power to break the vicious circle by virtually exterminating mosquitoes indoors by spraying the houses at intervals of a few months. This possibility lies beyond the span of years selected for this essay, but is one of the reasons for undertaking a study in the medical geography of India during a recent period. This new power marks a revolution, a turning point, and must be referred to again in the conclusion of the whole work. Meantime, it may be that the chief profit from a study of the maps of 'fevers' compared with the malaria map is the suggestion that the greater recorded mortality in the northern two-thirds of the sub-continent must be due to the extraordinary importance of other diseases, especially in the cool weather.


DYSENTERY. 1921-1940
0
Miles
500
DYSENTERY-Histogram of estimated standard deviation. 1921-40
No. of districts
Standard deviation
AVERAGES
Per 10,000 population
NUMBER OF DISTRICTS IN EACH CATEGORY
36 13 3
9 29 66
– 2 54
District Means per 10,000 population
DYSENTERY-Histogram of District Means 1921-40
No. of districts
District Means per 10,000 population

24 A


DYSENTERY. DISTRICT MEANS. 1921-40
Per 10,000 population
No. of districts
27
18
41
71
95
0
Miles
500

24 B


DYSENTERY. VARIABILITY. 1921-40
No. of districts
20
33
56
46
26
31

24C

CHAPTER 6.

Dysentery and diarrhoea

These diseases are not very accurately recorded - indeed it would be impossible for even a doctor to do so without laboratory findings to narrow the possibilities proffered by the clinical picture, and still less of course can accuracy be expected of the ignorant and illiterate laymen often responsible for the records. The maps are interesting, however, if only because the distributions are so different from any others in the whole series. The peninsula, the Assam valley the few British districts in the nothern hills stand out in all three maps of this group of diseases, in quite remarkable fashion. The combined map is figure 24A, means alone are mapped in figure 24B and variability alone in figure 24C.

On the combined map, the central black patch is still present though less continuous; but on the map of means alone it appears almost continuously over the median value. Variability is high.

East of Bombay, much of the plateau has high means, with high or medium variability, and this extends to the western seaboard in the south of the province (in the Bombay Karnatak), persisting thence along the coast into the Madras Karnatak and into Malabar; then it sweeps south-east to include much of the plateau portion of Madras, significantly including much of the country of 'tank' irrigation, and continuing eastwards to include all the south-eastern coastal lands except the tip of the Tanjore delta. The Orissa delta and adjacent Ganjam have high means, and high and medium variability respectively, and like the central black patch, they represent an overlap between the areas classed as high on this map and those appearing as high in most of the other maps.

To conclude the treatment of the peninsula, the interstices are filled, with few exceptions, by Districts with medium means and high or medium variability. This notably includes the Godavari-Kistna delta and adjacent coastal plains. The restricted areas classed as low include a group running north to south in the middle of Central Provinces, Western Khandesh on the plateau north-east of Bombay City, and coastal Ratnagiri south of Bombay City.

The maps of means alone and of variability alone suggest that there is significance in these broad trends, and the two maps correspond very closely indeed, so that there is a high degree of correlation between areas of high incidence and of high variability. These diseases, omnipresent though they be in India, yet tend to be epidemic in character.

The rest of the high values in the combined map are in the northern hills or hill-foot Districts, from Rawalpindi in the north-west, intermittently - and with a great lacuna in Nepal - to Lakhimpur in the far north-east. Again the variability is mostly high. The separate maps confirm these findings.

There are strikingly low means, with variability medium or low, in nearly all the Indo-Gangetic plain, from the Indus delta to western Assam and the Bengal delta. The few exceptions seem to be associated with large cities, notably Calcutta, Benares and Lucknow. Again reference to the maps of means and of variability alone shows that much the greater proportion of values below the median are in this tract of country.

Discussion

The northern plain, of low incidence and variability, includes irrigated and unirrigated desert and semi-desert, hill-foot terai in various climates and in various stages of reclamation from the wild, flood-plains and deltas in arid and in humid conditions, and also in various stages of evolution of the deltaic land-forms ....each of these with different conditions of water-table and water supply, and different cultural features. Equally great contrasts may be found in the environments of the peninsula. Yet common features there must be in relation to this group of diseases within these two great divisions of the sub-continent. The groupings on the maps are not simply by provinces, and it would be only as the result of the most incredible coincidences of poor recording that the cumulative errors from such myriad and diverse reporting agencies in the many thousands of towns and villages should have combined to present such a clear-cut pattern. It might be expected that there would be considerable overlapping and blurring between cholera and dysentery, and it must occur in individual cases, but the maps are clearly differentiated. One possibility is that typhoid fever or enteric may be particularly widespread in the peninsula; this disease is widely believed to account for heavy mortality among Indian children, although most adults have apparently a high degree of acquired immunity. It is difficult to imagine why any of the great intestinal diseases should particularly select or particularly shun say the Ganges flood-plain, or the tank irrigation country of the south. Further examination of the statistics, and of the characteristics of the various climates, season by season, along with the social environment and other elements in the physical environment, may yet throw further light on this question.

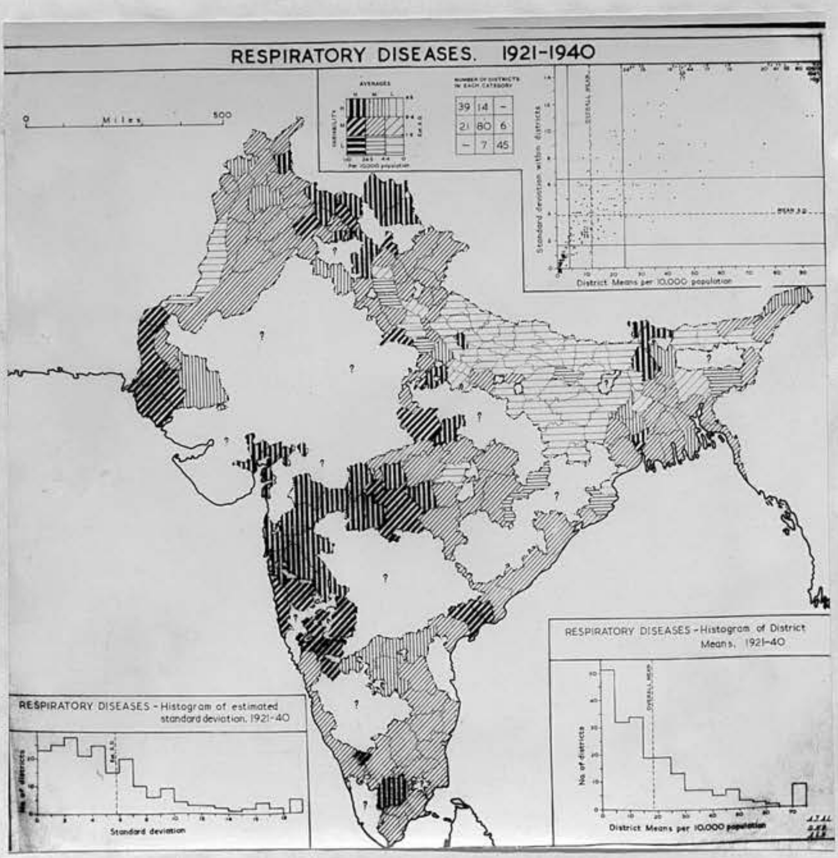
The writer believes that if malaria were to be drastically reduced, as is now possible given the funds etc., that the intestinal diseases would be the next most menacing aspect presented at least in the immediate future by the many-headed monster that is the public health problem in Indo-Pakistan. In this case there is no <u>deus ex machina</u> to break the vicious circle - only education in better standards of personal and environmental hygiene will prevail. Because of this peculiar importance, some further discussion of this map, although fruitless of conclusions, will be presented. Cholera is, of course, also an intestinal disease, which is much more accurately known and which has a much bigger literature; it will be discussed in chapter 8.

Dysentery is above all fly-borne, while the enteric group are predominantly water-borne although flies are also important.

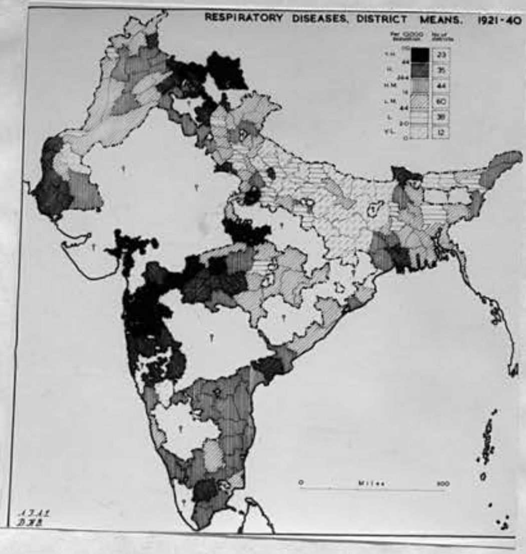
The low night temperatures of continental India which are hostile to the house-fly seem at first sight to offer some correlation with the low areas of figure 24B; but the high means of northern hill Districts are inconsistent with this view. There is some impression in medical circles that areas of ample and long rainfall and particularly of constantly high humidities tend to have a constant increment of these diseases, and to be associated rather more with amoebic dysentery which similarly yields a more continuous stream of cases compared with bacillary dysentery; whereas the drier areas of shorter seasons with temperatures and humidity suited to flies, tend much more to have explosive epidemics and to have a somewhat higher proportion of bacillary dysentery which is the most epidemic form of dysentery. (Dunbar 1930). This may possibly be shown in Central India, but there is not really a well-marked contrast with coastal and deltaic areas of the south which have the high humidities and long rains but no real indications of a tendency towards endemicity.

From the point of view of water-supply, it is reasonable to point to the Plateau as distinctive, with its stretches where the solid rock - broadly granitic or of ancient sediments in the south-east and volcanic in the centre and north-west - is overlain by the looser body of weathered material, lateritic over most of the area, and making up the black soil groups in the west centre of the plateau especially. Here are permanent masonry wells, often step-wells, going down to the water-table presumably often at or near the solid rock. And in the south-east is the tank country in which the water of the same stream is used in succession for several small indigenous irrigation schemes, inevitably becomes very polluted, and is also used for a wide range of domestic purposes. The step-wells are known to be associated with the spread of Guinea-worm (a small crustacean acting as intermediate host), and might spread enteric also, while the potential dangers of the tanks are certainly great. These areas, then, are at least distinctive, but they do not appear on the map as markedly different from low coast-lands and deltas of the peninsula. As far as these lowland areas are concerned, it is interesting that the Orissa delta appears high, and similar though less marked conditions seem to maintain in the extreme south-west of the Bengal delta, and are then succeeded by the very different incidence of the Indo-Gangetic plain. (This north-eastern corner is perhaps one area where confusion with cholera may be suspected). The wet alluvial plain of the upper Assam valley differs markedly from analogues in East Bengal or the terai of the hill-foot of the lower-middle Ganges, and in this case again some mis-classified cholera cases may be present.

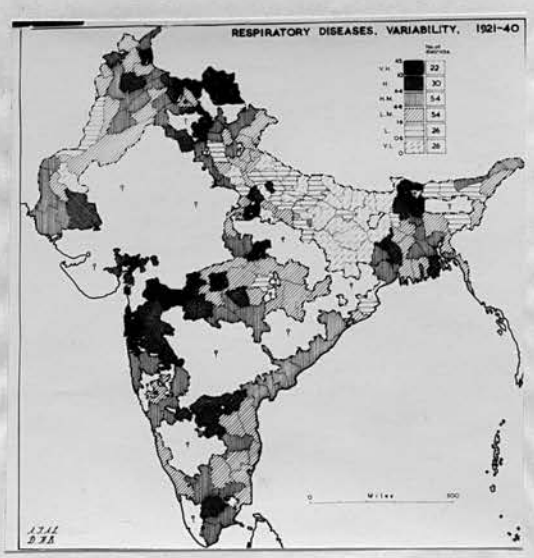
Rice-lands, millet-lands and wheat-lands are represented in both the heavy areas of the peninsula and the lighter area of the northern plain. Areas of continuously poor rice diet or rice-and tapioca diet as in Malabar are not clearly distinguished from areas of better diet in good years but subject to famine or near-famine at frequent intervals; yet loss of tone of the gut under either set of circumstances may well have a bearing on the incidence of intestinal diseases. Nor is there any comparison possible on the maps with analogous areas in respect of diet, from the Indo-Gangetic plain.


RESPIRATORY DISEASES. 1921-1940
0
Miles
500
AVERAGES
VARIABILITY
Per 10,000 population
NUMBER OF DISTRICTS IN EACH CATEGORY
39 14 –
21 80 6
– 7 45
OVERALL MEAN
Standard deviation within districts
MEAN S.D.
District Means per 10,000 population
RESPIRATORY DISEASES - Histogram of District Means, 1921-40
OVERALL MEAN
No. of districts
District Means per 10,000 population
RESPIRATORY DISEASES - Histogram of estimated standard deviation, 1921-40
No. of districts
Standard deviation

25A


RESPIRATORY DISEASES, DISTRICT MEANS. 1921-40
23
35
44
60
38
12
0
Miles
500

25 B


RESPIRATORY DISEASES. VARIABILITY. 1921-40
22
30
54
54
26
26
0
Miles
500

25C

CHAPTER 7.

Respiratory Diseases

Perhaps it is well at the outset to state that this category includes some but not by any means all the deaths from pulmonary tuberculosis, from pneumonia, perhaps some plague, and very notably those from influenza, including the aftermath of India's heavy share of the pandemic of 1918. This series of maps shows a highly individual distribution, which is at least not wholly fortuitous.

The combined map is figure 25A. The eye leaps first not this time to the central black patch - though that is present in some degree - but rather to a heavy mourning border on the western seaboard, and including the whole of Gujarat and a large part of Sind almost for the first time in this series of maps. Then the high areas stretch through Central Provinces, with a break in the centre, and reach up towards the unfortunate hill-district of Kangra, not this time by a tentacle, but by stepping-stones. Variability is medium in Sind and southern Bombay, otherwise dominantly high. Elsewhere, there is a patch of high means and high variability in northern Bengal, from sub-Himalayan Darjeeling to cone-foot Dinajpur, and another patch consisting of Calcutta and its western neighbours. Part of the Godavari-Kistna delta has high means and medium variability, and Madura in the centre of the south of the peninsula has high mean and high variability.

The low means are strikingly concentrated in central or eastern United Provinces, continuing into Bihar and just into north-western Bengal and including hill-foot, flood-plain and plateau - and the coal-mining and steel-manufacturing areas. Western Assam and one District of Bengal just south of the Khasi hills also have low means. Variability is low throughout. Elsewhere, Districts with low means are very scattered.

The medium means include most of North West Frontier Province, Punjab, western United Provinces, and show a rather striking concentration in the east and south of the peninsula.

The histograms of means and of variability alike show that a large number of Districts are scarcely affected - or do scarcely any recording yet.

The maps of means alone and of variability alone are figures 25B and 25C respectively. They confirm the broad trends outlined above.

Discussion.

The outstanding features of these maps are almost certainly due to the influenza pandemic of 1918 and its aftermath. It did not suddenly vanish - perhaps it has not done so even yet - but retreated, rapidly enough in parts, but lingering in Punjab and especially in Bombay for several years at least. This fact goes far towards explaining the bias to a westerly distribution. At the same time, the map serves at least to remind one of the view that in relation to tuberculosis, India may be in a transition stage between a relatively highly immunised country like Britain, and a continent still relatively virgin territory to the tubercle bacillus, such as Africa, whose inhabitants are correspondingly highly susceptible to severe infection. In India, it may be, the cities have relatively highly developed acquired immunity, while the rural population remains as yet highly susceptible. One must bear in mind the overcrowding in rural and urban areas alike, but especially the dreadful industrial slums which still dominate India's industrialising areas. Moreover, most industrial areas still tend to have a large proportion of their labour force consisting of temporary and tubercle-susceptible immigrants to the cities, who, returning to the villages, often mortally ill, spread the disease among the susceptible population there. Thus the cotton manufacturing area of Gujarat appears as having very high means and variability. The industrial workers in Bombay City, most of whom live in unspeakable one-room tenements, are known to spread infection among the rural population of the surrounding Districts, notably Kolaba and Ratnagiri. There is little doubt that this factor has at least added to the blackness of the high patches in the west.[1] Calcutta and its immediate neighbours on the west appear in a similar light, and it is known that incidence of tuberculosis within the city increases in the slum areas surrounding large industrial establishments. The coal and iron areas of West Bengal and of Bihar, on the other hand, do not stand out on the present

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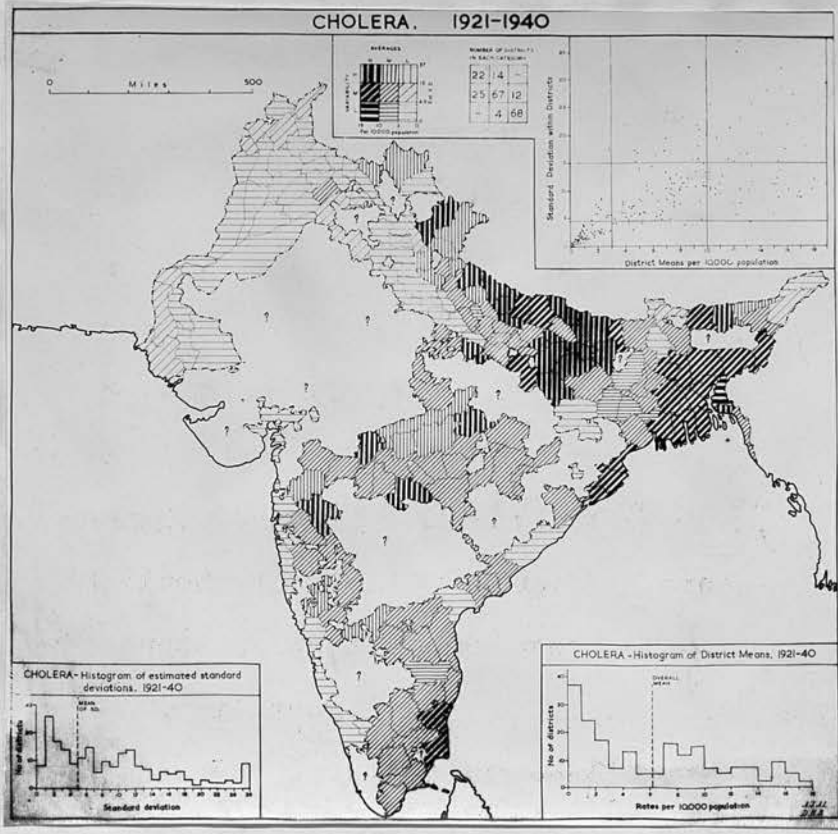
1. This is the subject of many comments in the health reports, e.g. Annual Report of the Public Health Commissioner with the Government of India, 1933 (Lt. Col. A.J.H. Russell) Delhi, 1935, p. 82.

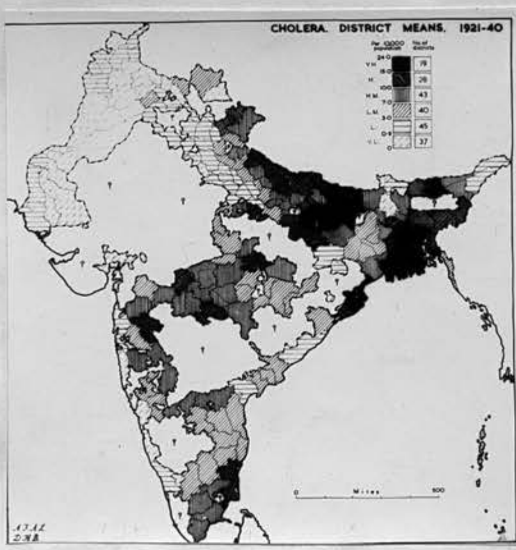
maps. Sind and Punjab again have long had a considerable urban tradition, accompanied by strict observance of purdah which fans incidence and makes detection and treatment extremely difficult among the female population; no doubt tuberculosis is a factor in these black areas also. In the south, one black patch is associated with the cotton town of Madura although plague may in fact be the cause here, and another with the Godavari-Kistna delta, where the rice diet is known to be peculiarly ill-balanced.

In all the northern two-thirds of the sub-continent, moreover, pneumonia in the cool season is probably a factor of real importance in swelling these figures. There is doubtless an association on the one hand with influenza and on the other hand with poor harvests in variable rainfall, on eroding soil and possibly with periods of economic depression. It should be said, however, that the Director of Public Health in the Punjab observed during the slump of the early thirties that the peasant was better off, in that in times of poor prices he kept and ate a bigger proportion of his harvest, and improved his nutrition significantly (Punjab Health Report 1931). In the northern hills, Kangra and Darjeeling have high incidence, the former is noted for a comprehensive and severe disease-complex associated with poor nutrition, and the latter possibly figures so high because of its reputation as a health resort - though hardly one ideal to tuberculous cases - and yet is only one of a group along with its southerly neighbours.

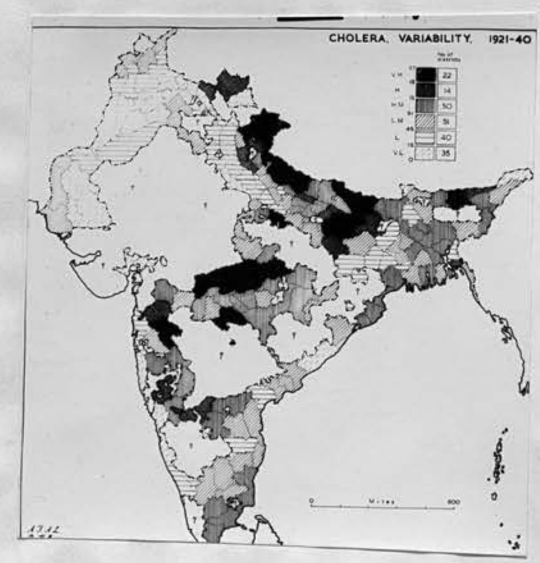
The writer suggested that if the new anti-malaria techniques were employed virtually to banish malaria, the major public health problem, from Indo-Pakistan, the intestinal diseases might in the short term be the most formidable problem of actual disease still to face. It this be so, it seems not unlikely that the greatest long-term problem might prove to be tuberculosis. For in such industrialising countries the roots of future trouble are well established and yet the imperfect degree of immunisation results in a severe and rapid course of the disease, comparable to that seen in children in Western Europe. The infection rates are quoted by one authority as being from about 20 to 35 per cent in rural areas and 80 to 90 per cent in urban areas, while in Bengal the percentages actually suffering illness because of their infection were about 7 per cent in the cities, 4 per cent in industrial areas (presumably jute-mills etc. which are not necessarily truly urban), and .6 per cent in samples taken in rural areas. (Ukil, quoted in Bhore Report 1946). The rapid advance made by the disease in the last two or three generations gives a peculiar importance both to the surveys suggested by the Bhore report and to the re-housing of the rapidly growing urban populations, and their education in the use of space.


CHOLERA. 1921-1940
0 Miles 500
AVERAGES
NUMBER OF DISTRICTS IN EACH CATEGORY
22 14 -
25 67 12
- 4 68
Per 10,000 population
Standard Deviation within Districts
District Means per 10,000 population
CHOLERA - Histogram of estimated standard deviations. 1921-40
No. of districts
MEAN OF SD.
Standard deviation
CHOLERA - Histogram of District Means, 1921-40
No. of districts
OVERALL MEAN
Rates per 10,000 population

26 A


CHOLERA. DISTRICT MEANS. 1921-40
Per 10,000 population
No. of districts
19
26
43
40
45
37
0 Miles 500

26 B


CHOLERA. VARIABILITY. 1921-40
No. of districts
22
14
50
51
40
35
0 Miles 500

26 C.

CHAPTER 8.

Cholera

The remaining maps, for cholera, plague and smallpox, are (figures 26, 27 & 28). These are the most reliable of the series, for the great epidemic diseases are the most easily recognised of the diseases and the least erroneously recorded of all these phenomena. No doubt the recording suffers from a certain amount of concealment, but probably of cases rather than of deaths which are necessarily more difficult to hide. It should be stressed, however, that together these three diseases normally account for less than five per cent of the total mortality.

Cholera, a water-borne and fly-borne disease par excellence, has recognised endemic homes in the Bengal delta and the lower Ganges flood-plain, and to some extent in at least the Orissa and Tanjore deltas.

These features are shown quite clearly in the combined map (figure 26). Only one District-in eastern Bengal - shows high means with low variability, the stigmata of severe endemicity, using the writer's rather arbitrary yardsticks; but there is high mean with medium variability in much of deltaic Bengal, especially the otherwise healthier and more prosperous active delta of the east, whose more frequent flooding discourages malaria but brings cholera as an aftermath. Similar grades are found in the deltas of Orissa and Tanjore. In part of the Brahmaputra flood-plain, there are high means with medium and some notably high variability.

North-west of the Bengal delta, beyond a lighter patch, is the great black area of the lower and middle Ganges, extending to some Districts on the plateau, and particularly stretching north of west along the hill-foot. Some Districts on the plateau edge and along the northern hill-foot have medium variability, but high variability is dominant, so that on the present criteria it is the epidemic peaks rather than the endemic foci that dominate the picture of cholera in this area. Other Districts with high means are scattered on the plateau, and there is one in the northern hills (Garhwal); significantly, these have high variability.

Among the areas with low means are plateau Districts of Bihar (one of them including the steel-manufacturing area), along with some plains Districts of eastern Bihar and western Bengal, and some hill-foot Districts of north-western Bengal and eastern Assam. Some Districts on the eastern seaboard away from the deltas have low means, as also has much of the western coastal belt. All the north and west, i.e. Sind, North West Frontier Province, Punjab and United Provinces as far east as the Ganges, are also low - the significant exceptions are the unhealthy hill District of Kangra, and Lahore, dominated by the great city of the same name. In all these areas of low means, low variability also predominates. These light shadings do not reveal the occurrence of periodic sharp outbreaks coinciding with the 12-yearly Hindu religious fair at Hardwar (where the Ganges emerges from the mountains) and also the lesser outbreaks connected with the Hindu fair at Allahabad. These epidemics would doubtless be much worse were conditions of climate and water-table favourable to the spread of the disease at the actual time of the fairs (see Appendix B). Control measures among pilgrims have had some success in diminishing these epidemics and preventing their spread.

The histograms show that many Districts are little affected, and the correlation diagram shows how most Districts with low means are also generally free from all but quite local epidemics.

Medium means fill in the rest of the Gangetic plain east of the Ganges itself, accompanied by more low variability in the east and more high variability in the west, away from the greatest single endemic home, Bengal. The greater part of the peninsula has medium means, and on this occasion Central Provinces are included, so that the great central black patch is here greatly attenuated although it appears as severe enough on the map of means alone. Medium variability predominates but with some high variability in the north and west. The severe incidence on the periphery of the Central Provinces is attributed to invasions due to incoming pilgrims from Nasik and Pandharpur in Bombay, from Allahabad on the Middle Ganges, and from Puri via the Middle Mahanadi (see Appendix B).

The maps of means alone and of variability alone throw some further light on this disease (figures 26B. and 26C). For instance, the grade for very high Districts in the map of means brings out the importance of the north-east corner for high incidence - the Bengal delta, the Orissa delta, the lower Ganges flood-plain.

Turning to the map of variability alone, the endemic homes appear much less dramatically, although they have values mostly above the median. Within the area which has a serious cholera problem, the very high variability is found especially on the periphery, i.e. away from the endemic homes, and on the distal margins of the areas of medium means. Beyond, there is a precipitous drop to the little affected areas, in which, however, local outbreaks may have a sufficiently sharp and tragic impact on the people.

Discussion.

Much of the relevant medical literature has been systematically reviewed in Appendix B which shows the wide range of possible relationships which may yet prove to be important. In the wide view which seems to the writer most appropriate to the present essay, however, the maps may be re-examined, regarding cholera as a disease mainly water-borne but partly fly-borne (other methods of spread being less important on the present broad scale).

The main endemic home of cholera, in Bengal, or as some would have it, in East Bengal and lower Assam, is associated with a constantly high water table with favourable amounts of organic matter present in surface waters over wide areas, and of suitably saline content in the broad tidal belt. There is a considerable rainfall for the greater part of the year, and a high relative humidity for even longer. In the active delta of East Bengal, and nearby areas of Lower Assam subject also to sheet-floods, the cholera incidence falls during the floods but this does not save them from severe endemicity since cholera increases as the floods recede. Nor does the greater prosperity of this area seem to affect the issue appreciably.[1] Some customary use of latrines does exist in this region, but while this may afford a useful basis for future reforms, it only acts favourably at present if the stools are passed so that they are disposed of by salt water - elsewhere there is much polution of wells, tanks and rivers used for drinking, bathing and domestic purposes. The east-coast deltas are not dissimilar, but probably resemble West Bengal rather than East Bengal.

The hill-foot or terai zone and again the broad flood-plain of the middle Ganges contain endemic foci although epidemics spreading therefrom dominate the present series of maps. The endemic foci have a high water table over much of their area, maintained over fine silts or heavy clays, ample organic content in the surface waters from the fields and settlements, and climatic conditions which favour the disease directly or through raising the water-table to nearer the surface, although for a shorter time than in Bengal. All the areas considered so far are mainly rice-growing.

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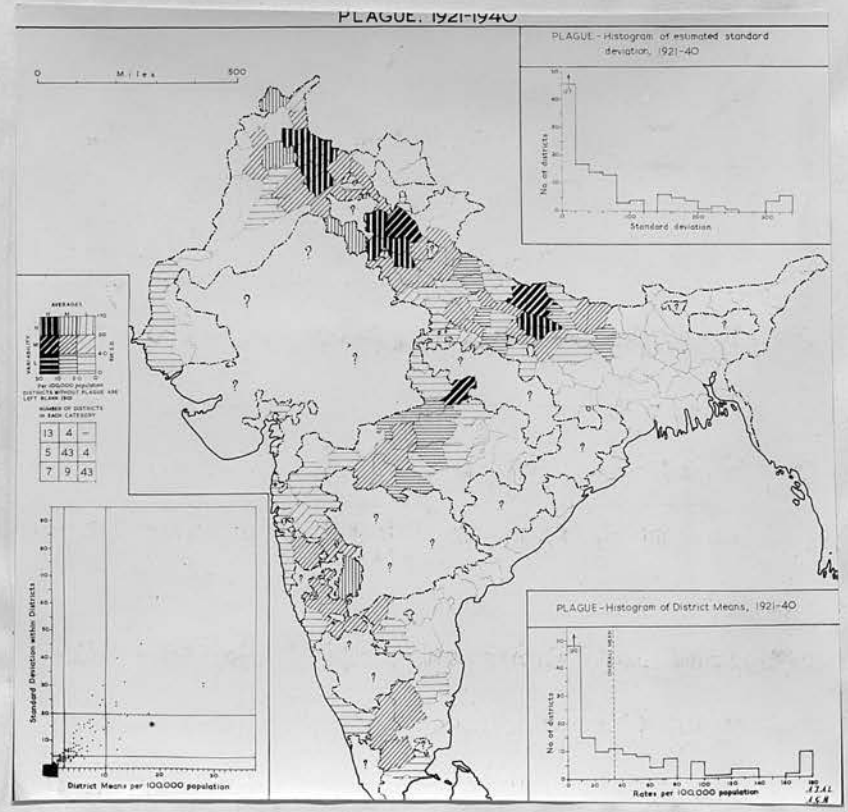
1. Passmore has said that none of these three great epidemic diseases, cholera, plague and smallpox, appear to be related to factors of nutrition.

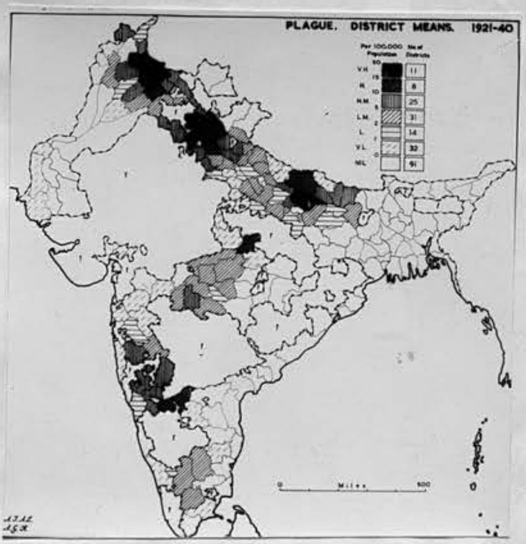
The epidemics are mainly in drier areas, and it appears that they are more severe on the Plateau, especially the rather unstable areas of wheat and millet (and cash-cropping of cotton). The epidemics also occur in the tank irrigation country of the South-east, in severer form than in the epidemic areas of the Indo-Gangetic plain. This is interesting in view of the greater severity of dysentery and diarrhoea in the peninsula seen in the maps. In these epidemic areas both on the Plateau and the Indo-Gangetic plain, there are only ribbons of flood-plain in which the conditions approximate in some respects to those in the endemic areas.

Over wide areas there is dependence on permanent wells, step-wells and draw-wells, although of recent years there is an increase in well-protected wells with pumps, and to some extent on deep tube-wells, for instance in Punjab. It may be that wells sunk in the relatively shallow weathered layer of much of the Plateau draw their water from their immediate environs to a greater extent, and are subject to more pollution from surface wash, than is the case in the great alluvial plain. There a permanent well may be sunk to a solid foundation of one of the lenticular deposits of clay found as result of the activities of former rivers as the infilling progressed. The clay may trap water percolating downwards, or the well may be fed from water trapped underneath the impermeable layer, often as a semi-artesian source. It is possible that water from such wells may more often be subject to purification by percolation than is the case on the Plateau.

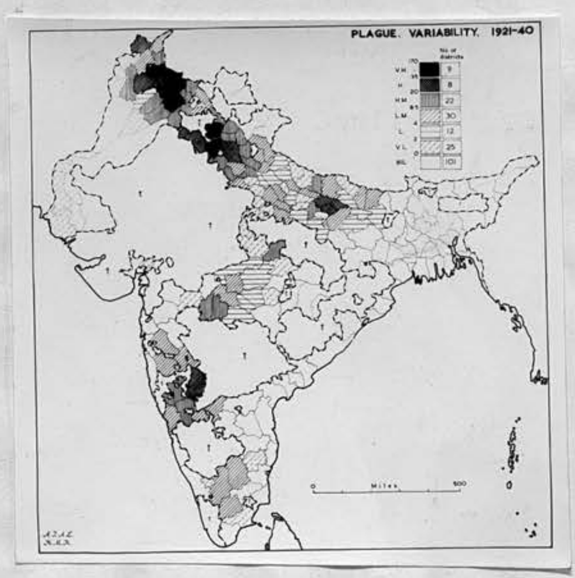
The whole epidemic area shares the characteristic of having only a relatively short season when there coincide considerable rainfall, high humidities, high water-table and much surface-water. They are areas of variable rainfall, and rainy and humid years can be linked in a general way with cholera years. The potentialities for cholera will be the greater if the people are in poor general health after a series of the lean years which are equally characteristic of these regions, and if the lapse of some years since a cholera epidemic has increased the available number of 'susceptibles' (but see footnote p. 45). The relations of the 'cholera year' with the 'climatic year' may well be susceptible of further geographical analysis. In so far as epidemics are explosive and mainly water-borne, however, such relationships must be indirect, acting through changes in the water-table and surface pollution. In so far as they may be somewhat more protracted, and almost certainly mainly fly-borne, the relationships must again be indirect, acting through the bionomics of the house-fly.


PLAGUE. 1921-1940
0
Miles
500
PLAGUE - Histogram of estimated standard deviation, 1921-40
No of districts
Standard deviation
AVERAGES
VARIABILITY
Per 100,000 population
DISTRICTS WITHOUT PLAGUE ARE LEFT BLANK
NUMBER OF DISTRICTS IN EACH CATEGORY
13 4 –
5 43 4
7 9 43
Standard Deviation within Districts
District Means per 100,000 population
PLAGUE - Histogram of District Means, 1921-40
No of districts
Rates per 100,000 population

27A


PLAGUE. DISTRICT MEANS. 1921-40
Per 100,000 Population
No of Districts
V.H. 11
H. 8
H.M. 25
L.M. 31
L. 14
V.L. 32
NIL 91
0
Miles
500

27B


PLAGUE. VARIABILITY. 1921-40
No of districts
V.H. 9
H. 8
H.M. 22
L.M. 30
L. 12
V.L. 25
NIL 101
0
Miles
500

27C.

CHAPTER 9.

Plague.

During the period under review, plague had sunk to relatively low proportions, although in the highest year, 1924, over 360,000 deaths were recorded. While this represented only 1.5 per thousand of the total population of India, plague is a rather localised disease, and the mortality in Punjab was over 12 per thousand in that year.

The combined map shows that the endemic foci near to the point of entry of the disease at Bombay City in 1896, persisted though with reduced intensity and amplitude of fluctuations (figure 27A). South-east Bombay had mostly medium means with medium variability dominant; one should think not only of the relatively dry plateau, with its variable rainfall and harvests and its cash cropping, but also of its urban centres, several of them becoming industrialised, which are largely the actual foci of the disease. Similar grades and a not dissimilar environment are found in the dry plateau and famine zone of Madras. In Punjab and the Upper and Middle Ganges, endemic foci with surrounding epidemic areas show dramatically in the three black patches; there is some medium variability, but high variability dominates. Surrounding these are aureoles, coalescing in places of medium means and widely differing variability. The central area which has so often appeared as a black patch has only one District with a high mean (its variability is medium), but it has other features deserving study.

It has a great extent of medium means, of which part has medium variability but rather more is of low variability; this is more suggestive of a large endemic area than anything else on the map. This is clearly only a first inference based on the writer's arbitrary numerical manipulations, and can not as yet be accepted as of epidemiological significance.

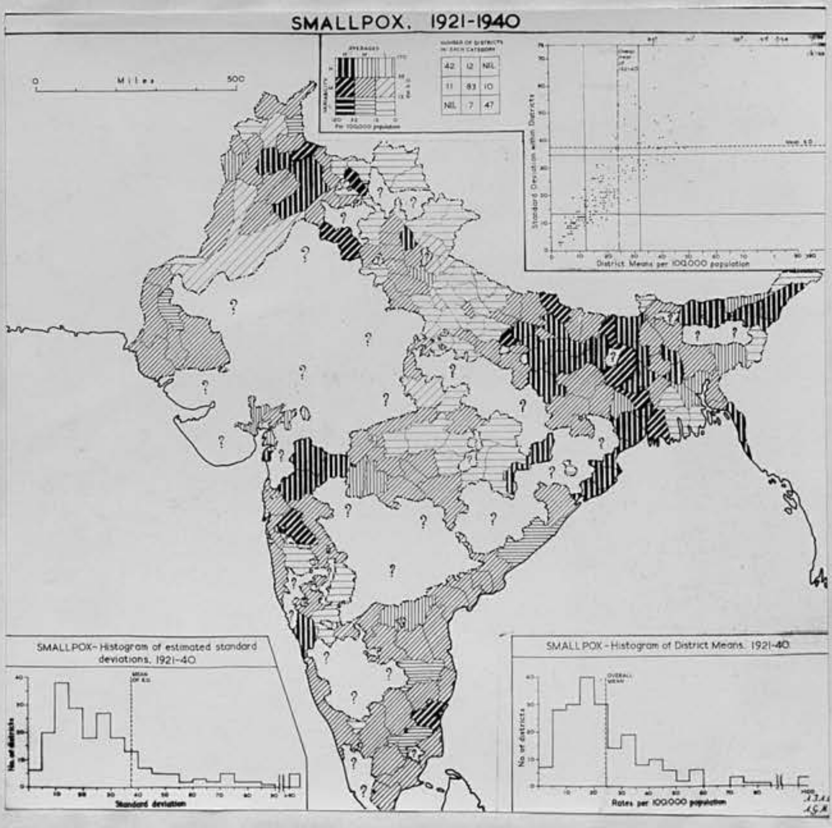
Surrounding and linking these areas, are Districts of low means mostly with low variability. These are often very low indeed, and grade into the plague-free areas, which comprise all the humid east, but not so much of the humid west.

The map of means alone is figure 27B. It serves to emphasise the three centres on the plains, as containing patches of the very high grade, while the map of variability alone shows that it was in the semi-arid and rather highly urbanised north-west that the greatest variations occurred (figure 27C).

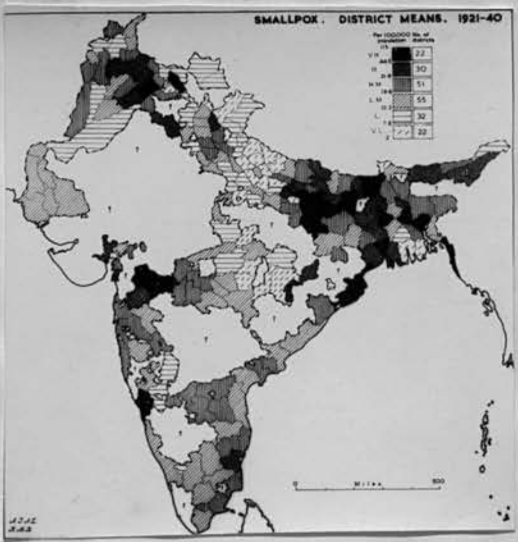
Discussion

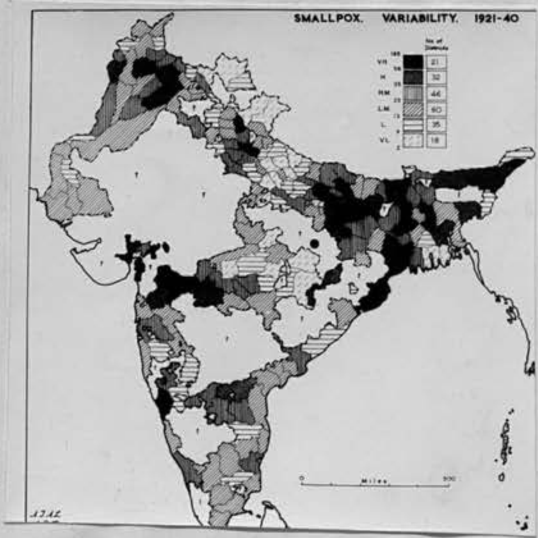
Clearly this disease shuns the humid heat of the east, and favours the drier areas which have also certain human factors of overcrowding, rural and especially urban, and mostly close purdah as well. On the other hand, certain broad controls by hot dry air have long been recognised as affecting plague through their effect on the life and activities of the rat-flea which carries the infection from rats suffering from the disease often by leaving the animal after it has died of plague. Thus plague fails to maintain itself at temperatures over 80° F. if the saturation deficit is above .3 inches, but it may maintain itself, or even increase, at higher temperatures if the saturation deficit is less. (Brooks 1917, quoted by Buxton 1937-38). Seasonal incidence varies greatly as between north and south, but a brief examination of the important northern area may show the complexity of the problem. The seasonal maximum is generally in the late cool weather and early hot weather, but it follows, and especially in severe epidemic years, very high humidities (of 80% and over) in the rainy months of the cool season. These conditions favour propagation of rat fleas, but no simple relations can be looked for, since special sorts of micro-climates are involved, like those of the interior of dark and overcrowded houses, the area between clothes and skin, the fur of a rat, and the very stable conditions in the rat's burrow. On such complex factors depends the survival of the fleas if the host-rat dies of the infection. Again it is the larval flea which is in general so very dependent on high humidities - the adult flea which is the actual vector is able to cut down its transpiration rate very drastically when the saturation deficit is high, and is able to restore its fluid content to normal at its next blood meal (Buxton 1937-38). Very hot dry weather, however, is unfavourable to the development of the actual power to infect human beings, even although the fleas have already become infected (George etc. 1934). Moreover immunity varies widely among the rat population in a way not explicable from the history of the present outbreaks, and there are wide differences in the acquired and administered immunity of the human population. And the main species of fleas differ considerably in their efficiency as vectors of plague; their geographical distribution is therefore important, but is not fixed and permanent - the main vector in India, for instance, Xenopsylla cheopis, is known to be carried in cotton bales, and to be diffused from cotton mills. One might add that habits and traditions in matters affecting personal and communal hygiene some of which are related to climatic factors - may also affect the distributions.

Here again Rogers has attempted forecasting of plague by study of weather statistics, based on the inhibiting effect of high temperature accompanied by the high saturation deficits already referred to. Here is a complex and a challenging problem, about which one can say no more at present pending a much more systematic study of the literature. Plague is one of the diseases whose potentialities have assumed quite different proportions since the revolutionary discovery of DDT and other modern insecticides. Indeed anti-malaria campaigns using residual insecticides have in some areas reduced plague as a sort of by-product. A recent study of the endemic areas of the sub-continent aims at helping to define areas where control of rats and fleas is likely to give lasting results (Sharif 1951). It may be that geographical techniques in the study of 'plague years' and 'climatic years' may have a contribution to offer but the labour involved in exploring this possibility can not be expended during a general survey like the present work, in view of the small percentage of mortality and morbidity due to this disease.


SMALLPOX. 1921-1940
Miles
0
500
SMALLPOX - Histogram of estimated standard deviations, 1921-40.
Standard deviation
SMALLPOX - Histogram of District Means. 1921-40.
Rates per 100,000 population
District Means per 100,000 population
Standard Deviation within Districts

28 A.


SMALLPOX. DISTRICT MEANS. 1921-40


SMALLPOX. VARIABILITY. 1921-40

28 B

28C.

CHAPTER 10.

Smallpox.

The combined map is figure 28A. The central black patch is again absent. There is an area of high means in the western Bengal delta; but not, significantly, in the active delta of the east. The Orissa delta is included, and the group stretches north to include the terai areas of Bihar, and envelops also the middle and lower Ganges flood-plain and some plateau Districts. Variability is mostly high, with some medium Districts which may represent severe endemicity. Assam, as in several maps, appears as an epidemic area peripheral to the Bengal delta, with high means and variability over much of its extent. The area surrounding Madras City has high means and variability. North Kanara (Bombay Karnatak) and Bombay City are also in this grade, representing severe epidemic conditions. So far, these areas of high incidence fall within humid India. East and south-east of Bombay, however, are black patches consisting of much less humid plateau Districts, largely urban and industrialising, mostly having high means and variability; Poona, however, has medium variability suggestive of more endemic conditions, and recalling the suggestion that the amplitude of fluctuations in Bombay is becoming less, along with a decrease in case mortality (All-India Health Report 1935). Again away from normally humid India, there is a group of Districts with high means and variability in Punjab, and here there is a strong tradition of urban life and strongly nucleated rural settlements also, accompanied by strict purdah. The famine zone of south-east Punjab has high means and medium variability, and a similar grade is seen in several hill-foot Districts.

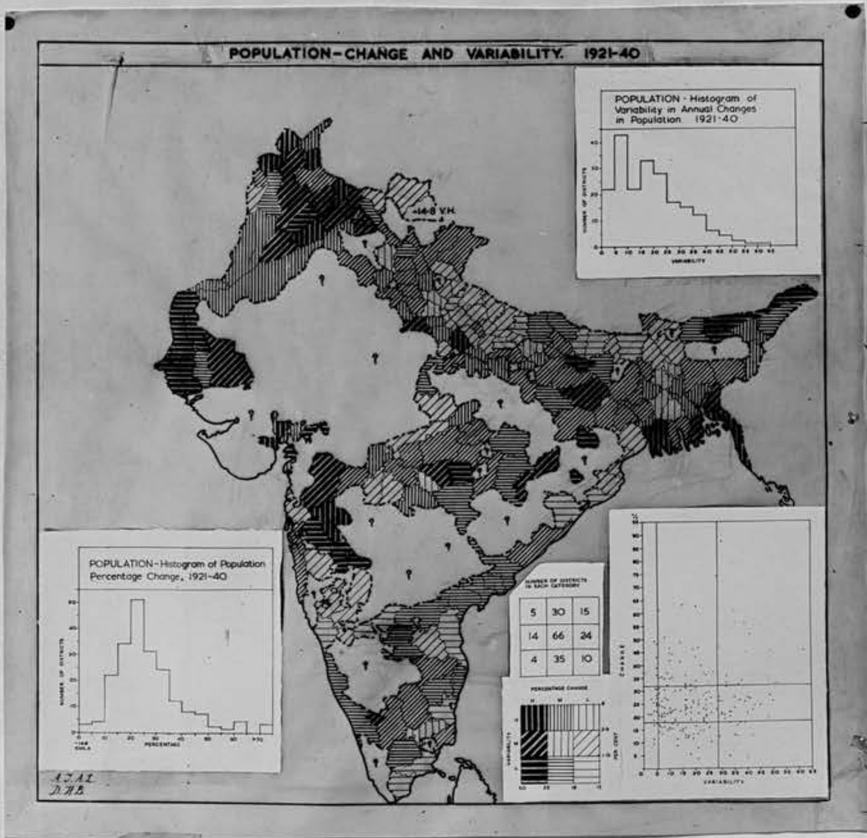
The areas of low means chiefly include a great north to south belt in Middle India, from Kangra in the Punjab Hills, through central United Provinces to eastern Central Provinces, and much smaller groups in the Eastern delta of Bengal, parts of eastern Assam, southern Bombay, south-western Punjab, and of North West Frontier Province.

The areas with medium means fill the interstices in all the lower Ganges plain, Punjab and North West Frontier Province, surrounding the cores of black, and appear also in western Central Provinces and most of Sind. As so often, most of the peninsula appears as very much a medium area. The variability is also dominantly medium in this epidemic disease where there is such a strong correlation between intensity and variability. This property also imposes a strong similarity on the maps of means alone and of variability alone (figures 28B and 28C). They do serve, however, to emphasise the groupings suggested above, and to confirm that they have some reality.

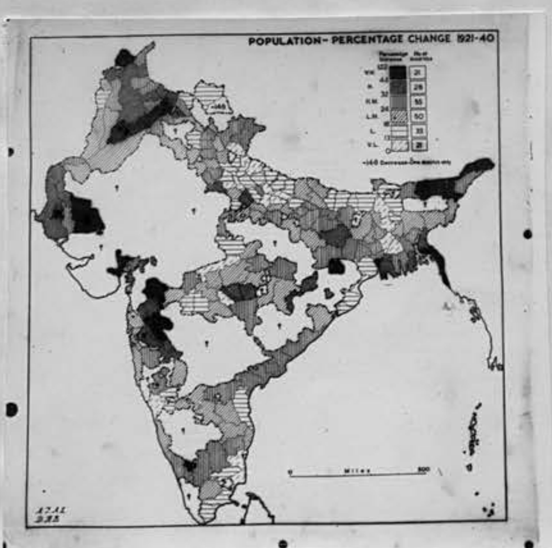
Discussion.

Little has been said in the present essay directly concerning the aetiology or transmission of the various diseases, except in footnotes and Appendixes A and B which are part of a farther but only partly written phase of the work. It may be well to point out, however, that smallpox differs from nearly all the diseases considered in that it is a virus disease transmitted from human to human by droplet, direct contact or indirect contact. It is also notable that India is a reservoir of world significance for severe smallpox infection (variola major) although some authorities have found signs of change, with decreases in the very high case mortality from 40% to just over 20%. (All-India Health Report 1935).

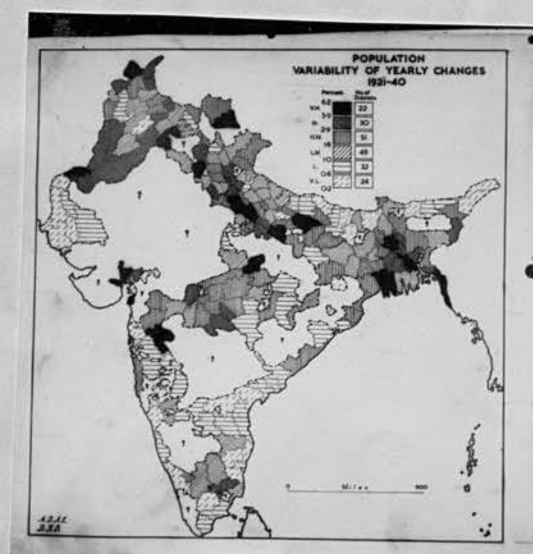
Smallpox in India has been regarded as conforming somewhat to the same distribution pattern as cholera, with home areas typically in the humid east. The writer is not certain that this is borne out by the present maps, or by study of the maps of incidence in particular years which appeared from time to time in the All-India Health Reports. The maxiumum seasonal incidence is in the early hot weather except for south eastern Madras, where, especially if the rains of the retreating monsoon should fail, there is a cool season maximum. Correlation with certain degrees of absolute humidity has been suggested (Rogers 1926). Later it was suggested that the study of relative humidities might give better results - again with forecasting in mind (Russell et al. 1930). Smallpox has a cyclic rise and fall in India occupying five to seven years, probably associated with the building up of a sufficiently large non-immune population by birth and under modern conditions by relaxation of vaccination precautions. The peaks do not occur everywhere at the same time, and climatic factors may well be arbiters in the particular years chosen by severe epidemics, e.g. it has been suggested that epidemics in the humid east are associated with failures of the monsoon. (Rogers 1926). There is good reason, however, to associate this disease as much with overcrowding especially in cities and towns, as with climatic factors.


POPULATION-CHANGE AND VARIABILITY. 1921-40
POPULATION - Histogram of Variability in Annual Changes in Population 1921-40
POPULATION-Histogram of Population Percentage Change, 1921-40
5 30 15
14 66 24
4 35 10

29A


POPULATION- PERCENTAGE CHANGE 1921-40

29B


POPULATION
VARIABILITY OF YEARLY CHANGES
1921-40

29C.

CHAPTER 11.

Population change & variability in change & regional variations therein.

It will be recalled that estimates of population were made for each inter-censal year during the period under review, for the purpose initially of calculating fresh and more accurate incidence-rates for the phenomena discussed in chapters 2 to 9 (see p. 4 and appendix D). These estimates were subjected to statistical analysis aimed at producing the maps included as figures 29A, 29B and 29C. The general method was that used by Geddes in his papers already cited, and need not be given in detail; but a similar classification of the results was used to that employed for the present writer's other maps, to make the whole series comparable, and using administrative divisions rather than Geddes' more advanced concept of demographic regions, for the same reason. Compared with figure 16, these maps show total change for a shorter period, 1921 to 1940, and the annual variability in the changes during that period, whereas Geddes dealt with the 50 years 1881 to 1931, while the variability was that revealed by the six decennial censuses concerned. During the twenty years now under review, almost all the Districts began with a set-back or lag in growth due to the complex of ills which followed the influenza pandemic of 1918, but soon recovered, and show very rapid growth towards the end of the period. The later years of the first decade therefore have a marked sag below the theoretical curve appropriate to the initial and terminal figures. The method of calculating variability by summing departures of annual estimates from the theoretical curve naturally shows Districts where this phenomenon is particularly marked, as having high variability. This special cause of high variability was undoubtedly important during the period under review, but it is so common that some irritating repetition is unavoidable in the ensuing analysis.

Figures 29B and C show change and variability in change mapped separately, but the main discussion is based on figure 29A, which is the combined map.

In Bengal, Geddes' map shows with diagrammatic clarity, the now well-known contrasts between the active eastern delta and the dying western delta, except for Hooghlyside itself, as well as the importance of such features as the old alluvium too subtle for the crude methods used in the present work. The new map is somewhat less clearcut. The east has an important area of high increase, and while variability is high or medium, this is due to the check in 1922 and to the greatly increased rate of growth in the second decade. The rest of the east shows similar variations and a medium rate of increase. The south-central delta, already known to be a transitional area is also in this group. Calcutta and the surrounding Districts have a high increase and a high variability due to similar dips in the graphs. The western delta, then, does not show stagnation at all clearly, and if Districts of medium increase be added, it seems that the industrial conurbation of Hooghlyside has counteracted stagnation to some extent beyond its own immediate site on the drained mud-banks of the Hooghly. Some observers from the field, however, have reported a reversal of the stagnation between the wars in purely rural areas, and it may be that in an area of hyper-endemic malaria which had yet only experienced it severely for some three generations, the surviving population was beginning to live 'on terms' with the disease. Yet stagnation is to be seen on the present map, southwestward from the Hooghly mouths, stretching to and beyond the Orissa delta. Here variability is low and medium, with repeated checks to growth imposed by endemic malaria and cholera - cholera is especially severe in the pilgrim centre of Puri (where the Juggernaut ceremony is held), and spreads in ideal terrain in the delta. Stagnation is seen also in a belt stretching south to north, from the north of the Bengal delta to the borders of the Himalaya. This belt is shown to be severely affected by disease in several of the foregoing maps and 'agricultural deterioration' is often reported by District Officers etc.. Here, variability is medium in the north and high in the south; in the north there was slow growth in the twenties and more rapid increase after 1931, but in the south two Districts have an even clearer picture of actual decrease in the twenties and recovery in the thirties.

In Assam, one of Geddes' regions of colonisation, there are several Districts of high increase and low variability, while others are consistent with this picture although less striking. One District in particular showed a sharp check to growth in the twenties, due to malaria and kala-azar, and epidemic cholera spreading from its main endemic home in Bengal.

As on Geddes' map, Districts of stagnation continue from northern Bengal along the hill-foot far to the west, but there is now a break caused by two Districts of medium increase and low variability, probably due to colonisation proceeding in the low-lying Gandak flood-plain. In the middle Ganges, stagnation continues, but with some replacement by more vigorous increase in the east, permitted by more reliable rainfall and flood-water, and in the west, where irrigation of the incised cones was proceeding. The centre of United Provinces stands out as a distinctive and generally unfavourable area in several of the maps of the medical geography. The rising urban centres of Patna, Gawnpore and Agra also stand out. Variability has no special features, except the complexity of its causation in the West, where cholera, plague and epidemic malaria are all important checks, contrasting with constant pressure by malaria in the east, especially in years of poor harvests. The hill Districts share the slow growth in the twenties, increasing in the second decade.

In the north-west, there is a striking area of high increase with high, medium and low variability. Geddes' 1942 map here shows along the hill-foot an area of high natural increase, a region of colonisation in the canal zone, and transitional types elsewhere. This is borne out by the present map, for the most part, but it is notable that the hill-foot zone shows much high variability.

In part, this is due to the greatly accelerated rate of increase in the second decade, and in part to fulminant epidemics of autumn malaria after a heavy monsoon or river flooding, of pneumonia in the cool weather, relapsing fever in the hot weather, and in 1924 by the last of the great plague epidemics spreading from the urban endemic foci. The colonisation area is still showing high increase, but only one District has low variability (Lyallpur) while Montgomery is high. Some of this variability is due to repeated epidemics invading even this prosperous area, but more is due to a lag in increase in the early 30's, and it seems that the world slump had some effect on population growth, probably mainly through curtailment of new irrigation works etc. Surrounding this north-western area of high increase are Districts of mostly medium increase, but some are low in the extreme east of Punjab and in the hills of north and west. Variability is mostly medium and high, and here repeated set-backs can be attributed to epidemics often associated with poor harvests and nutrition. Thus the easterly Districts had severe epidemic malaria in the mid-20's and famine accompanied by disease in 1922, 1924 and very notably in 1939-40. In the case of Sukkor and Upper Sind Frontier, however, the high variability is due to a very rapid increase in the first decade, damped down from about 1930 onwards, and doubtless due to the building of the great barrage; floods in 1930 accompanied by disease are also important.

The rest of Sind forms a group of Districts ofmainly high increase and mainly low variability, but because of boundary changes the three western Districts are slumped together here, and almost half their total increase is in Karachi City. In Thar Parkar, the high variability is again because of a very rapid increase in the first decade, greatly reduced after 1930. Compared with Geddes' map this group shows an extension of the colonisation type. The extension of irrigation failed to avoid an extension of the realm of malaria also, but no effect on population growth can be seen on this scale at least.

Gujarat, appearing as 'recurrent crisis' and 'intermediate' on Geddes' map, here shows as largely of high increase. Variability certainly appears as mostly high, but this is not due to sudden checks in growth, but to greatly accelerated growth in the second decade. At least in Ahmedabad, industrialisation in a rising cotton growing and manufacturing region is the cause.

Something similar is seen in the large plateau area east of Bombay City, classed by Geddes as of 'Recurrent crisis' type, but now with high increase and high medium and low variability. Bombay City itself was rather stagnant especially in the twenties while its near neighbours increased rapidly in those years. The coastal lowlands of Kanara continue to show stagnation, while the south east of Bombay province has low increase with medium variability due to sharp checks in the mid-twenties and the mid-thirties caused by lingering influenza and by malaria respectively - thus the south of the recurrent crisis zone on the plateau, unlike the north, retained its character, because ~~they have~~ it has not been transformed by industrialisation.

In all Madras, the only District classed as of high increase is the hilly area of Nilgiris; its medium variability is due to a rather unusual check in growth in the late twenties. The south of the peninsula continues to show much agreement with Geddes' picture of stagnation on the south-eastern delta and coastal lands, and high natural increase over a wide and varied terrain which interestingly includes the Godavari-Kistna delta despite its known poor nutrition and health.

Parts of the north-eastern bastion of the plateau show high increase, including the steel area of Singbhum and areas of agricultural aborigines like the Ranchi plateau. The rest of this tract, and all along the northern edge of the plateau - mostly showing stagnation in Geddes' map - here appear as a great stretch of medium increase. The variability is high, medium and low, but has a fairly consistent pattern, including the slow growth of the early twenties and another pronounced set-back in the thirties due to malaria.

Central Provinces appear on Geddes' map as having some areas of high natural increase, mainly in hilly forested areas. Doubtless these trends continue, but in the present map the central area of high growth seems to be due to the growth of manufacturing in Nagpur and other towns. The surrounding area, with mainly moderate increase and high medium and low variability, corresponds to Geddes' intermediate type, while stagnation is confirmed by the low increase and low variability of the Narbada valley and the Upper Tapti basin. Parts of this central area are known to suffer from severe soil erosion and backward farming, but the one District of this part of British India shown as decreasing in Geddes' earlier, that is 1941, map by administrative units, is now increasing. It is a pity that the present data do not extend to the several native states which showed a decrease in that map. In all the central tract, the variability whether marked or slight is due mainly to two sharp checks, that following the influenza pandemic and in 1939 due to an explosive epidemic of malaria.

Conclusion

In Comparison with Geddes' work of 1941-42, variations have been studied from year to year over a shorter period, instead of at decennial censuses over a longer period, but by similar methods, and along with the percentage change over the period. Even given this difference, and a different though overlapping period, the present work gives an interesting check, and over large areas earlier findings are confirmed and shown to have continued as far as 1941. Some differences, of course, arise, and some of these are of interest if only to illustrate the extension of a fuller use of the environment by irrigation, and again the erosion largely by industrialisation of some of the areas where groups of men have been at the mercy of their environment. Thus the demographic picture has changed in some parts of the zone of recurrent crisis; there has been a short period of great increase, not too seriously interrupted in the period under review - although one would not, of course, wish to contend that all is therefore well in the rapidly growing cities of India's industrial revolution. Again there has been erosion of the zone of stagnation, in part by similar influences, in part by the widespread quickening of population growth in the second decade of the period, and there is a strong suggestion that, in a short term study at least, there was a turning point of demographic history somewhere about 1931. Indeed this factor has rather swamped the picture of variability in change as far as the present method is concerned, especially where urbanisation and industrialisation are rapidly increasing; but there is also a lessened amplitude of year-to-year fluctuations - the Bengal famine of 1942-43 is of course outside the period. Relatively minor fluctuations did occur, and with considerable homogeneity of pattern over wide regions. Their local impact is serious enough; and they may be worthy of further study, and meantime mention has been made of important checks to population growth due to endemic or epidemic disease, or to famine, during the period. Considered purely as a demographic and geographical study, there has been much loss through restricting the study to administrative units, instead of replotting the data in demographic or geographic regions, but this loss may be compensated by the opportunity of examining at least some of the health factors involved on the similar maps already presented.

CHAPTER 12.

Aspects of village life in India.

In the Introduction the writer was able - using material and especially maps borrowed from others - to present some picture of the whole of Indo-Pakistan, from the point of view of physical and cultural geography; the treatment was naturally pointed as far as possible at the theme of this essay. It is clear, however, that certain other maps of the sub-continent would be desirable as an aid to a fuller understanding of the preceding chapters - and of other aspects of the medical geography not treated in the present work. Two such gaps would be filled by mapping the significant regional variations in habits and customs as they affect health and disease, and secondly by finding a cartographic technique to express the varying relationships between the quantity and quality of the food available to the nutritional needs of the people. The writer has been unable as yet to compile such maps, and it is partly for this reason that the present chapter is included. The endeavour is to offer by means of sample studies of villages in differing parts of the sub-continent some living picture of the interactions of the physical and cultural environment, including the diet and customs of the people, from the point of view of a medical geographer. These sample studies are so far based primarily on library work, using as sources the admirable topographic maps of the Survey of India, the Imperial Gazeteer of India, the partially completed book on Indo-Pakistan by A. Geddes, many papers in the Indian Journal of Medical Research and other journals, which will be separately acknowledged as far as possible, and to some small extent the writer's own observations in India. The writer acknowledges, indeed urges the need for the suggested general maps to be compiled, and for further sample studies to be carried out in the field rather than in the library, extending in due course to towns and cities as well as to rural settlements.

It must always be difficult to generalise about such a topic as Indian villages, for there are at least three-quarters of a million of them in the sub-continent, giving homes to almost four hundred million people, in very varied physical and cultural environments. Nevertheless, a first general description may be given, based on Baden-Powell's classic work:-

1) In most of rural India, there is some form of grouping of houses, recognised not only as a village but also as a community. In some large areas this grouping is almost absent - in much of the Himalayas, for instance, and other examples are met in the course of this chapter; this absence may be ascribed to factors of physical geography without being unduly deterministic. Sometimes the grouping is central and compact, sometimes there are several scattered hamlets. The building materials of course vary according to climatic needs and available materials. The agricultural villages grade through market villages to small towns, which however, are outside the scope of this chapter. In considering the sense of community, it is important not to exaggerate the

present or even the historical extent of communism in the original sense of sharing land, for instance; holdings are normally fragmented but individual plots, but apparently fragmented more through the particular laws of inheritance than through the decay of a system of holding in common. Certain economic functions are exercised in common, however, and will be dealt with presently.

2) A pond is almost invariably found, and the widely varying extent to which the water is used for various human uses - drinking, bathing, washing utensils and so on, makes it important to a detailed study in medical geography. The pond is often referred to in the literature as a 'tank', because in some of the Indian languages the word for a pond especially an irrigation pond approximates in sound to our word 'tank'. But there is no implication of regularity in shape nor of a concrete or metal lining. It may be the result of damming a stream for irrigation purposes, or even more commonly as a result of surface or seepage water filling a 'borrow-pit', that is the hole left after excavating mud for the walls or to raise the site of a house.

3) There is traditionally a dry dusty open space, acting as a cattle pound, and as a place where the dying village craft of weaving is practised, or indeed any other occupations demanding a fair amount of space.

4) There is the village tree or grove - perhaps a great banyan tree sending down aerial roots to form a grove in itself,

or a mango tree with heavy dark green foliage, giving good shade. This is the village meeting place, especially for the village elders, and sometimes has raised platforms of clay for squatting on.

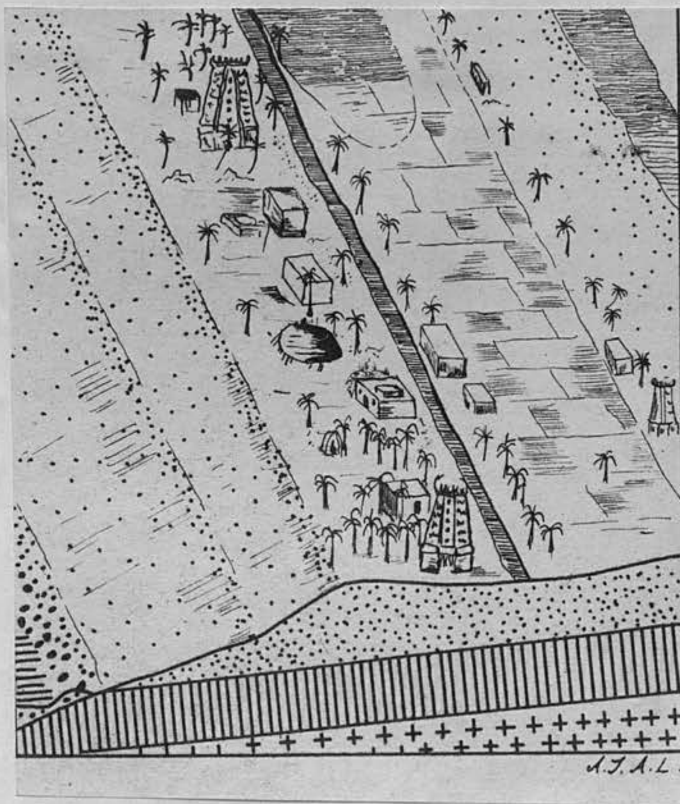
5) The village temple or mosque - or more occasionally of course a Christian church - often stands out, and a cemetery if it is a Muslim or Christian village. The Hindu temple is not always maintained as part of an organised church such as we are used to. There may be quite small altars, sometimes almost on a family basis, at which offerings of food are made to a Hindu god, sometimes widely recognised or sometimes quite a local god or spirit, perhaps associated with , a local feature - a particular tree, or stream or rocky hill - thus one can see how all embracing is Hinduism, and how it has an incredible power of absorbing other religions, from sheer animism to Buddhist and even Christian elements.

6) There are <u>some</u> communal economic responsibilities. The most widespread are the maintenance of village artisans - for instance the weavers already mentioned, or the village watchman who so far is responsible for the registration of health and vital statistics, or village menials such as sweepers - that is scavengers - washermen etc. There are also usually common grazing rights on adjacent lands, of rather variable legal status. Beyond these, there are many and varied village officials, some holding hereditary office, and varying greatly

30 Land-forms of Malabar coast...

in different parts of the country. The landlord-villages or zamindari-villages of most of the north are, on the face of it, associated with somewhat more democratic organisation of joint tenure and local government by a 'council of five' or council of elders. This council may have vanished or lost power, but it is a hopeful means of stimulating a sense of local responsibility in the zamindari areas. On the other hand, the intervention of landlords between the actual cultivators and the State has proved an adverse factor on the whole, and it must be emphasised that only proprietors have rights, - landless labourers or menials have none. In the south, where there prevails generally the ryotwari system which has given the name ryot commonly applied to the Indian cultivator, the land is usually held by owner-cultivators direct from the State, and village government and taxation is generally through an hereditary headman reminiscent of tribal organisation, often with an hereditary village accountant to assist him. Six villages will now be examined each in its geographical setting; some are actual villages, some rather composite.

Figure 30 is a diagrammatic sketch of the landforms in and around the first village, which is situated in coastal Travancore or Cochin. Here are the distorted deltas of the short rivers from the Ghats, giving the sandbars and lagoons of the actual coastal belt. Beyond are the laterised emerged plains, into which small but locally important flood-plains are incised some 20 feet or so. Inland again is a low peneplane then



31 Malabar village - land-use....

the main scarp edge of the Ghats.

The use of this environment is [illegible] t sketched on figure 31. The sandbars are used for coconut groves along with garden cultivation, the lagoons for fishing, for water transport including some by canal between lagoons, and for a slow and endless process of empoldering, of winning valuable rice-fields from the sea. The flood-plains, off this sketch, commonly give three crops of rice per year in the long rainy season here - and are fertilised with cattle dung and with green manure cut from the remaining woodlands. In the upper plain millet and tapioca (for the long rains permit the growing of such exotic tropical tubers), are grown by a sort of residual of tropical shifting agriculture, using ashes as fertiliser. All these are mainly providers of starch, of carbohydrates, but some oil crops and pulses are given by the upland cultivation, and some more, along with fruits and spices, from the garden cultivation around the settlements.

The settlement type is not one of well-developed villages, but gives a pattern of moderate dispersal of houses of the family group or "undivided family" of the Hindus; these houses commonly have rooms for branches of the family situated round a court-yard, and are separated from their neighbours by a stretch of orchard or coconut grove, or open cultivated land. The most prosperous are well built of brick, but the climate does permit of quite slight structures of thatch and bamboo.

The sandbars especially have been since time immemorial the site of a kind of garden-city development - a special variety of ribbon-development following the lines of the sand-bars, and occupied by a dense and industrious population. As an Arabic writer of the fourteenth century put it - 'The whole of the way by land down the coast lies under the shade of trees, and in all the space of two months' journey there is not one span free from cultivation; everybody has his garden, and his house is planted in the middle of it.'

In this region of almost idyllic beauty, the picture is not too unfavourable from the point of view of health. There has now been a long period of remarkably steady population growth, in these conditions of long ample and reliable rains and rather varied resources of food, although the occasional recorded famines due to failure of the rains have been most catastrophic. Malaria is present always, but is only of moderate severity except on the edge of the Ghats. The intestinal diseases, which one must consider second only to malaria in India, are interesting. These separate houses for the undivided families, normally have their own wells - sandbars, for instance give a good enough water supply under these rainfall conditions; for these reasons, the intestinal infections are quite extraordinarily variable from family to family, according to the source of the well water and conditions around the well, but the population as a whole is rather less liable than in some areas to epidemics sweeping the whole community. On the other hand flies do flourish in the humid heat. The most remarkable feature

32 A 'tank' village of Madras.....

of the health of these folk, however, is one which brings up an important point in connection with diet. The poor rice diet, supplemented increasingly by tapioca during the last fifty years, and by coconut oil, pulses, and in some castes by fish clearly permits survival, as the population increase shows. But there are no implications as to the quality, the health of the people. In these beautiful settlements there is for instance probably the highest incidence of stomach ulcers in the world - here far from the rush and stress of modern city life which are often associated with that group of diseases. The causation is not well understood, but there are strong indications that a high proportion of tapioca in the diet is of real significance and that the high incidence of cancers of the stomach is also linked with this in some way.

The next village is in the 'tank' irrigation country of Madras, in an area dependent on some 35 inches of rainfall mainly from the retreating monsoon, but commonly falling to well under 30 inches, and with occasional years of much heavier falls: In figure 32 is a village on a post mature, very gently rolling surface of Archaean crystalline rock, of which occasional scrub-covered whalebacks project through the lateritic soil. So also do the much more spectacular inselbergs or sugar-loaf residuals of a higher erosion surface. The shallow and gently sloping valley has been dammed at two points - and at many others off the sketch - by quite simple traditional means - not indeed to store a good year's rainfall against a poor year, for the high evaporation forbids that almost everywhere in India, but rather to spread out the watering of the most highly prized crops over a longer period in one year. Along and below the canals are palmyras, giving edible nuts, areca palms, giving the so-called betel-nut, and some coconuts giving fibre, food and thatch, and some mangoes and other fruit trees. Partly in their shade are the first, well-manured irrigated patches of vegetables, peppers, and the betel vines yielding the leaves which are eaten with the areca nuts. Beyond is the irrigated paddy, of which the main crop of course is here grown in the cooler season, but with amply warm temperatures for its needs. Some rice may be grown, too, on the silted head of the reservoir, for these shallow ponds are rapidly silted up under present conditions. The upland dry crops include poor millets - the oats of India as it were a crop eaten willingly only by people of low social standing, yet of nutritional qualities superior to rice. Ground-nuts are also grown on the upland, wherever the soil is sufficiently sandy for the plant to bury its head after the pea has formed. The groundnuts, however, are mostly for export.

The typical village site is near the end of the dam. The village form is a rather loose aggregation, with one distinctive feature associated with the Dravidian south where the caste system is particularly well marked - namely that the village tends to contain two separate groups or hamlets - one for the upper castes, cultivators and others, - note the temple in this Brahmin village - and one for the low castes and casteless people like sweepers, oil-men and leather workers who handle filth or material from the dead body of the sacred cow. Conditions in the low caste hamlet are often very poor and backward.

This ancient system is usually held to stabilise conditions, and indeed such a village is normally fairly well-fed and prosperous. But even with the help of irrigation, too many of these villages are subject to severe hardship if the retreating monsoon fails, and should there be a sequence of years of low rainfall, then disaster follows. There was a severe and widespread famine just before Census records began, and the story told by the census totals up to 1941 is one largely of a fairly steady recovery. But the rains have failed in this area these last six years, and today there is real famine, with actual deaths from starvation despite the great efforts made by the new Government to help.

These indigenous irrigation works are associated with constant and extremely patchy incidence of malaria, which at worst is very severe indeed. Moreover, in the nature of things much water is used for bathing and washing utensils, and even for drinking, which has already been used for irrigating well-manured fields upstream, and is heavily polluted. Intestinal diseases are therefore severe, the more so because poor sanitation is almost at its most unhealthy in the rather loose type of grouping of houses.

In figure 33 is sketched something of the environment of

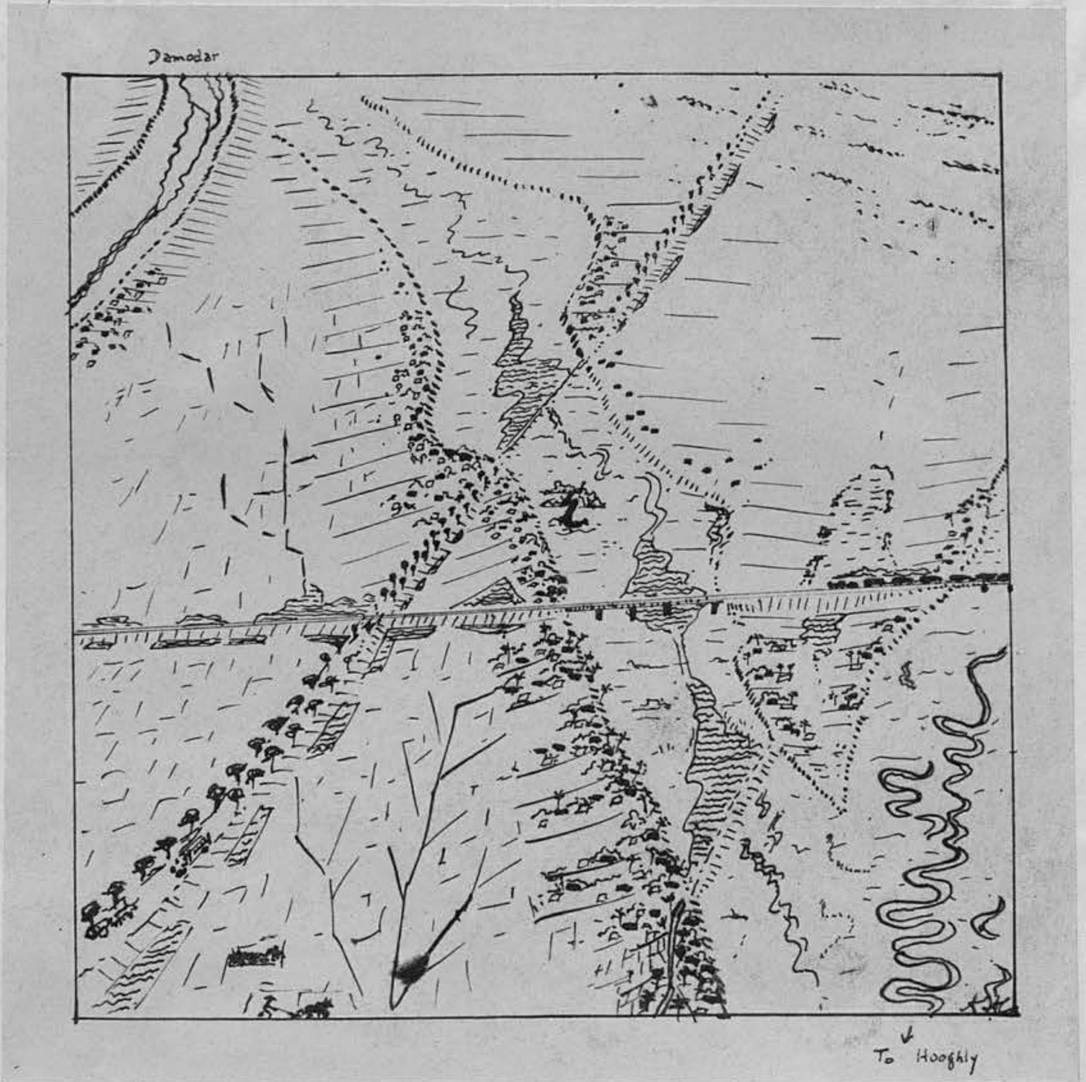
33 Village in the eastern 'active' delta of Bengal.....................................

a group of people in the active delta of East Bengal, getting their living from a land of sheet-floods, of constantly shifting deltaic banks, and of those hollow islands offering new and potentially good land if the water can be drained off and held at bay or at least under control (See also figure 3). A favourite settlement site is on a concave bank, despite dangers from the great powers of lateral corrasion of a main distributary channel of a senile river. The small bluff, perhaps a few feet high, gives better drainage, especially as the original spill-bank deposited by flood-water has been heightened, perhaps initially by wind-blown sand in the dry season, and subsequently by artificial means - it is commonly said that $2\frac{1}{2}$ acres are excavated to give one acre of land suitable for living on.

The settlement sites are of island character in several ways. They are literally islands, as I have sketched some here, in the flood season, when transport is entirely by boat, and is much easier than in the dry season when even agricultural operations are carried out from boats. At other times they give islands of trees in a grassland and arable landscape, and in the hot season islands of green among the little embanked stubble fields. And they are islands of garden cultivation of special crops, in rice and jute lands.

There is little true village character to be found, although some villages are 'manufactured on paper' for administrative purposes. For the causes of this dispersed type of settlement among a very dense rural population, one must look to the physical geography, certainly, and along with it to the Bengali tradition of the house again for the undivided family though no longer always Hindu, with its own orchard, garden, and tank, separated by field or grove or tank from its neighbours. If there is a large island-site, there may be as many as 100 or 200 families, with some community of feeling, but a mere handful is more common, and therefore there is a lack of formal meeting places for talk, business or religion, though there are of course periodic visits to market by boat.

On the whole, remarkably good health is associated with an unusually reliable economic basis founded on turn on reliable rainfall, sheet-floods and renewal of land fertility by fresh silt. About 30% of such land is double cropped, and on the inland side of the delta - that is away from the salt water - about 50% of the land is commonly under a lucrative cash crop, jute. There has been a very rapid increase of population, associated with an import of rice (paid for by cash cropping), an export of people as colonists to the frontier lands of Assam, and on the whole accompanied by relatively high standards of material life. One factor is that the large Muslim population in what is now eastern Pakistan eat meat without hesitation when it is available, and have no scruples at all about eating fish, a plentiful food in a delta. A relatively good economic status, then, does help health, but along with that one must remember that the flushing of water channels keeps down the malarial mosquitoes. Again, this is one of the very few areas in the sub-



34 Village in the western 'dying' delta of Bengal 78

continent with any tradition of using any form of latrine; this keeps down hookworm, for example, and if these rudimentary latrines are sited, for instance, on the edge of an island and in the salt-water zone so that no drinking water is polluted, then the excreta are carried off harmlessly. In a big island, however, there is often more congestion, resulting in pollution of wells. Inland, again, pollution of rivers affects water for bathing, for washing utensils, and even drinking water. Moreover, flies flourish in the humid heat. So that the relatively good health is far from including an immunity from intestinal diseases. Yet the tradition of even rudimentary sanitation and the slightly higher standard of living give hope for the future, given patient understanding educational work, using education in a broad sense.

Figure 34 illustrates the setting of a village in West Bengal in the dying delta.[1] The village is between the variable torrential and destructive river Damodar, and the muddy ditch of the Hooghly - a distributary of the Ganges once important, but now carrying only a minor share of Ganges water to the sea. These are still deltaic lands, but no longer subject to the renewal of fertility through the silt brought by great sheet-floods

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1. In this section the writer has had the great benefit of using one of the very few surveys of general health for a small intensively studied area (Lal etc. 1944).

but rather subject to leaching by a moderate rainfall - about 60 inches, but varying between 35" (rather low for unirrigated rice) and 60 inches. Former stream channels, cut when the Damodar flowed much more directly to the Hooghly now carry only local drainage, and they are no longer flushed of mosquito larvae by flood waters. The water is in places ponded back by small-scale irrigation works, using simple lifting apparatus to water nearby fields in the cool weather and early summer. The streams and ponds - and other sheets of water to be mentioned, are largely overgrown by the water-hyacinth, the 'lilac devil', which gives harbourage to the larvae. Stagnant water is also provided by railway and road embankments, mostly built heedless of water flow, by the borrow-pits from which material for the embankments was dug, and by the tanks - almost one per house, most of which have ill-maintained fringes harbouring larvae, and too seldom a population of larvae-eating fish. There are drainage works in the lowest lying areas, leading ultimately to the Hooghly, but these need improvement - and maintenance.

The use of this environment in this case includes a dormitory element - 8% of the population travel to Calcutta daily to work, going some 30 miles by rail. The rest of the people, however, depend on the land, and 70% cultivate their own land. Four-fifths of the land is cultivated, the rest being occupied by houses, streams, roads and railways etc. - i.e. there is little unused land. The autumn rice harvest dominates in the land-use, being three times the summer harvest, three times the jute (very different from the proportion in the eastern delta) and six times the fruit and vegetable acreage including betel leaf gardens to supply the Calcutta market. The paddy harvests last the local people for 6 or 9 months - some of the high qualities are sold as cash crops - and there must therefore be important cash sales to buy food for the rest of the year. One form of cash sale is unfortunate - fruit and vegetables whose Vitamin C is badly needed by the local people, are sold to Calcutta. Again, there are many cattle, about one for every two people, but their condition and breeding are poor, bulls actually outnumber cows, and of course in a predominantly Hindu area none are slaughtered for meat; milk yields are miserably low, and what milk there is, is sold off to the Calcutta market, although it is desperately needed locally. Children are not weaned from their mothers until about 2 years, because of custom no doubt, but a custom bound up with the lack of cow's milk; one must add that there are some advantages in this, under present conditions of education and hygiene and sanitation, but it is symptomatic of bad condition of life for mothers and children. Similarly the few eggs - another high-value food - are mostly sold off to the city. This may seem a twisted version of the familiar spheres of economic influence round a great city, but one must remember that there was said to have been a falling of nutritional standards in the Home Counties when the Milk Marketing Boards came into existence in Britain.

There is perhaps rather more grouping of houses into a village form, under these drier conditions and in this dying

55 A house in West Bengal....

delta, but there is less tying to the highest available ground, and the tradition is generally the same one of the house for the undivided family, rather separate from its neighbours. The digging of tanks, and the building up of house sites, remain.

Figure 35 shows a good house in West Bengal, with its courtyard, its thatched rooms for branches of the family, and little separate rice stores. Often the courtyard is covered with trellis work, on which some kind of climbing plant is growing, often bearing pumpkins. Near the house are seen the tank, and date-palms to be tapped for syrup or toddy.

The health of this community is unsatisfactory, although it has at least been carefully measured by Indian public health workers, and improvement is going on. The drawing shows so much stagnant water that it is no surprise to learn that malaria in this area is as near hyper-endemicity as is anywhere in the sub-continent, and that it is a constant drag not only on population growth but on the vigour of the people. But malaria is not the only such drag. Certainly water supplies are reasonably satisfactory - most of the people use tube-wells for drinking water, although there is only one such pump for every 80 people. Few now drink from tank or streams - mostly old women especially widows. (Hindu widows are no longer required to throw themselves on their husband's funeral pyre, but except in advanced circles they tend to have a low social status, and in some cases, such as these old women, are almost outcastes). But utensils are washed in polluted water, and the mouth is washed out in the course of washing or bathing, so that intestinal diseases can spread in these ways. One must stress that these are not dirty people, they bathe daily, and pay great attention to ritual cleanliness, but need patient help in re-drawing their standards on modern lines instead of age-old beliefs. Disposal of faeces is poor - the people go anywhere where there is a little shade or shelter, the women nearer their homes and often to the sloping sides of the nearby tank, where they are hidden from general view so that tank water gets severly polluted on this account alone. Flies flourish for most of the year. Again there is some over-crowding at least, even in these rural surrounding - incomparably more of course in the city slums. And overcrowding accompanied by ignorance of the mode of spread of say tuberculosis or the infectious variety of leprosy is a real danger. These factors then, along with the slight but general malnutrition and the export of the high-value foods to the city, result in a most depressing complex of poor physique, poor active health, that terribly wasteful combination of a high birth rate and a high infant mortality rate, and high and constant malaria, intestinal diseases, measles, influenza and pneumonia in the cool weather - pleasant to the European, but cold to the ill-clad and ill-fed Bengali peasant, with his few lengths of cotton cloth, his one hot meal in the evening, and cold breakfast in the very early morning on left-over rice. Yet signs of a regeneration of vigour are present in parts, and given wise leadership this society may attain a new and healthier equilibrium with the resources of its

36 Air photo of a village in Central India.

environment, and resume its former intellectual hegemony in eastern India.

Figure 36 is an air photograph from Central India, of the northern slopes of the plateau, where the main Indian peneplane, it is surmised, has been gently warped, to dip farther north under the alluvium of the Gangetic plain.[1] Yet here is? an air photograph which might almost be of England - perhaps a farm-village in the Yorkshire Wolds in a dry summer where indeed water-supplies were almost as primitive as in India until a few years ago. In Central India as a whole, a lateritic soil has been stripped of scrub forest by plough and grazing animals, and at worst has developed badland topography through gullying by grossly accelerated soil erosion, or in places a bare gravel surface like a red slag tennis court, or even a pavement of indurated iron oxides. In the picture, however, are seen the stubble fields of wheat and millet grown by dry-farming methods including repeated shallow ploughings and cultivations, along with some oil-crops such as sesamum, and pulses to provide protein. In some ways this zone as a whole belongs to the rice-and-wheat lands of the Ganges, where these two staples are both grown according to the season and the range of soil types and soil moisture conditions. Irrigation is practised on a small scale round wells, but there is no stabilising tradition of larger

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1. Material has been woven into this account from McCombie Young (1927).

scale irrigation except in a few cases where tanks are so used which were originally built for religious purposes. In the area seen in the photograph, however, there is no alleviation in the landscape of dry cultivation. And in a deforested landscape, nearly all the cattle dung is burned as fuel. Only valued crops are manured - perhaps a little sugar or some opium poppies near the well. And when the monsoon breaks, the sheetwash sweeps over the ground so impregnated with top-soil that it looks almost like a mud-flow or a very liquid lava-flow, as it glides, semi-viscous, into a gully or over a river-bluff. The rainfall averages about 30 inches, but it commonly falls below 25 inches and more rarely it is excessive; this amount comes in torrential falls of which much runs off quickly, and the monsoon storms are here markedly local and patchy. In many ways instability is the key-note, and this is carried through into conditions of health and population.

The village type is clearly much more nucleated than we have seen, with streets of houses with mud or brick walls, or bamboo at worst - but this last is now distinctly unfavourable in the cool weather. Roofs are commonly thatched with semi-cylindrical pantiles, although thatch is also found. No village pond is to be seen, and there is reliance on wells, probably reaching down 20 feet or more, to an aquifer in the peneplaned pre-Palaeozoic rocks. Provided the well has a cover or a raised rim, and the masonry is not broken, the water supply will be good. Masonry wells with steps down to the water are less favourable because of their association with infection by the Guinea-worm. A well should not of course be sited near a polluted tank, as is quite commonly the case. And clearly wells which receive dirty or suspect receptacles are less favourable than those fitted with a pump, however simple. Disposal of faeces is not good, but in this open country, the hot sun quickly renders filth innocuous for most of the year. Malaria again is not normally a serious problem although there are occasional catastrophic epidemics in the autumn following an excessively heavy monsoon, especially if the harvest has failed. On the other hand, the people suffer from chest and lung complaints in the cool weather, and were among the worst hit in the great influenza pandemic after the First World War, which killed several million people in India. Again, these bamboo and clay houses have always harboured rats; in the present cycle of plague - only some 70 years old, dating from its arrival by sea to Bombay and other ports - these rats have proved very susceptible to plague, and if they die of it in their burrows in the house walls, their fleas seek a new host and quickly pass on the disease to human beings. Between the wars, this area continuously had serious plague, and had several very sharp epidemics indeed.

Moreover the saying - 'one lean year in three, one famine year in seven' may well apply to this part of India; when famine comes, its effects are heightened by certain economic evils connected with land tenure. Here, as all over the peasant East, the head of the family too often falls into the hands of the

37 A village from Sialkot District, Punjab hill-foot ....

money-lender, usually through extravagance in celebrating a marriage. Largely through this cause, there has grown here a class of landless labourers, working for the new owner of the land (often the money-lender himself) only for a supply of food, i.e. he is paid entirely in kind. In a famine year the rice crop will probably fail, the millet crop almost certainly will, if the drought holds through the cool season the wheat crop will do no better, and the oil crops and pulses, the high-value foods, will at best be poor. One crop does succeed in such years, sometimes sown and sometimes partly at least self-seeded. It is a kind of vetch called lathyrus sativa, whose black pods yield seeds which can be ground into a yellow flour to make bread. (This is a bread-eating area). If bread containing over half of this vetch-flour is eaten for over six months, a considerable proportion, perhaps 10 per cent, of the young male population are liable to be paralysed from the waist down, for life. It seems to be a form of poisoning rather than of mal-nutrition, and there is little doubt about its causation, for Hindu villages are much more affected than Muslim villages where more varied diets are taken even in a famine year - including meat from cattle dying because of the drought. So much, then, for a village in a rather unhappy area, where variability, instability sharp even catastrophic checks are most striking phenomena.

Finally of these village studies, in figure 37 is sketched a village from Sialkot District between the Ravi and Chenab rivers now in West Pakistan. An area of long settlement based on well-irrigation has been chosen, rather than a canal colony. It may be helpful to refer back to figure 3. The particular village is in the zone of heavier soils and emergence of springs, between major river fans, and at the foot of the zone of coarse gravel fans from short streams on the outer ranges of the mountains. Farther east, in conditions of higher rainfall, such a zone would still include malarious forests, in various stages of colonisation, but here the internal expanding frontier against the wild has long since vanished from the plain, and we are dealing with a zone of ancient and continued dense settlement, founded on well-irrigation in the presence of a high water-table. It was indeed subject to occasional famines prior to the release of population pressure by the opening of the canal colonies farther south and the expansion of well irrigation locally to allow some safety margin to the remaining population. The rainfall is about 35 inches average, but is very variable, from 10 to 60 inches.

The well is of fundamental importance, and one must think of a well-built masonry well, built down to strike one of the lenticular clay patches deep underground, the legacy of changes in depositional conditions in recent geological times. As already noted in another context, the clay traps water, sometimes above it, but sometimes below it, with some hydraulic pressure behind it, giving a semi-artesian effect which brings the water part of the way up the shaft, and reduces the labour of lifting it. The water is raised by a Persian wheel or other simple apparatus, although modern pumps for deep wells are found now.

For the benefit of the beasts and their driver, shade trees are usually found by the wells. Such a well irrigates say 20 acres, the irrigated parts of the scattered holdings of at least four or five families. The irrigated patch receives manure from dung that has escaped use as fuel, from night soil and refuse. Cattle and sheep brought from adjacent hill country for the purpose are folded on the most valued fields to manure them, and camel and goat dung is also used. The most valuable crops, cotton, sugar, opium poppies and vegetables, are hoed and weeded, and wheat, the highly esteemed staple food and cool season crop, and rice as a summer crop of appreciable importance, are also grown on irrigated land. The dry cultivation area gives more hazardous crops of millets in the monsoon, and pulses and wheat in a good year in the cool season, as well as some pasture for the cattle, which are however, stall-fed in such an intensively cultivated area - an example for most other parts of the sub-continent.

The village type here is that of all the upper Ganges and north-western India, and indeed stretches beyond Pakistan towards the Middle East. It is a markedly nucleated village, owing to factors of water-supply and defence; indeed in many cases the villages were walled at least into this century and in some cases probably are so even today. Even thus far from deltaic conditions, the raising of house sites by digging mud from a nearby pit has gone on from time immemorial, and in this different climate this process, and the building upon old broken walls of houses, has raised some village sites considerably above the general level of the plain. The borrow-pits fill with water in the rains, and are an important factor in causing autumnal malaria. The house form has changed to the thick mud walls familiar to us from the Holy Land, with the flat roof to give an extra 'lung' in the cool evening times. The house is cool in summer and warm in the quite sharp winter nights, although of somewhat doubtful ventilation. The dominance of Islam accentuates the tendency for the houses to turn a blank blind wall to the closely built village streets, and for air and light only to circulate through the internal courtyard.

The general health is less bad than in most parts of the sub-continent. This is related, in important part, to the eating of wheat - not as white bread, although that is becoming fashionable with deleterious effects - but as wholemeal savoury pancakes eaten along with pulses or meat dishes. Meat is eaten fairly freely in this Muslim area; and with a lingering tradition of pastoral forbears, and a relatively high standard of material life, much more milk is drunk and butter eaten. This generally favourable picture is qualified in ways peculiar to the region and village type.

Malaria is an autumnal disease, as has been shown which in the periodic very wet year swells to epidemic proportions, especially if the harvest is poor and malnutrition has lowered the normally good resistance of the people. This is an area where reliable forecasting of malaria has proved possible, allowing special measures to be taken timeously. Environmental hygiene is not good. The casual habits of the men in defaecating do not seriously affect health for most of the year owing to the cleansing effect of the hot sun, unless indeed wells used for drinking water are badly built or maintained. In the brief 'Bengal season' of the rains, however, fly and water-borne diseases get their chance, and there are sometimes very severe epidemics of cholera, usually following the periodical great Hindu religious fairs at Hardwar at the exit of the Ganges from the mountains. Cholera spread from village to village, up to partition at least, and even among Muslims, through the general custom of marrying only someone from the next village, and by the consequent intermingling of people from neighbouring villages at the elaborate celebrations, often during the cholera season. The case of women in purdah is unfortunate when hygiene is so primitive and houses so dark and ill-ventilated - and also in that help from male doctors is barred though there are only a handful of women doctors and nurses because of the purdah system itself. The health of the women has undoubtedly suffered compared to that of the men, except in enlightened families which, however, may increase rapidly in number in the new and vigorous republic. To take the example of plague we have already noticed, the older house-type is again a favourable harbour for rats, which are susceptible though probably decreasingly so of recent years, and from quasi-permanent homes in the great cities, plague periodically goes out in waves to attack villages like these, and the women in purdah naturally suffer severely.

One should perhaps add before concluding a rather melancholy chapter that not all Indian habits are unfavourable to health.

For instance food is often eaten direct from a cooking vessel, which reduces risks of contamination, and milk is almost invariably boiled before use which is certainly a good thing under present conditions in India. So that there were times between the wars when India troops living in conditions less favourable than British Troops had better health - admittedly in their own sub-continent, and with acquired immunity to certain diseases strong in the survivors to manhood from the terribly high mortality rates of infancy and childhood.

SUMMARY & CONCLUSION.

The aims and origins of the present work have been described in the preface. The geographic setting has been depicted in the introduction. The rationale and methods lying behind the writer's original maps are presented in Chapter 1, while a more technical description of the statistical methods employed, by Miss Elizabeth Gittus, is given in appendix C. The next nine chapters deal in turn with the distribution of births, deaths, infant mortality, 'fevers', respiratory diseases, dysentery and diarrhoea cholera, plague and smallpox. In each case one map shows the intensity of incidence, a second the variability of incidence, while the third shows intensity and variability mapped together. In each chapter the features shown on the maps are first pointed out and as a certain pattern of distribution is described, any association with other geographic distributions, of possible significance is noted along with such material from the official medical history of the period as the writer believes to be important. Then in each case there follows a Discussion, much broader and more free in character.

In order to equip himself for these discussions, the writer has read and summarised much of the medical literature relating to the environmental relations of disease, and also to nutrition and general health so far as these have been examined. In only two cases has this large body of material been tentatively re-sorted and set forth as a systematic analysis of the existing knowledge; this work is now presented as appendix A on malaria and appendix B on cholera. In the other chapters, the discussion has nevertheless been conducted with the literature in mind, not only concerning the nine subjects of the chapters, but several other topics - mostly concerning disease rather than health - of geographical interest.

Chapter 11 is an examination of population change and variability in change, planned jointly with Dr. Arthur Geddes and using methods mainly evolved in connection with his work in this field, but applied here by the present writer. This chapter differs from the others in that the treatment is more integrated in seeking to discover how the various strands already discussed are knit together with other factors of social and economic geography in producing the pattern of population change as a whole. The inter-actions of the many factors thus seen to be at work in the differential distribution of health and disease in Indo-Pakistan seem at times to be beyond the grasp of a single mind. It is to meet this problem in some degree that the scale is changed in Chapter 12 where these regional inter-actions are treated more intensively in a series of studies of villages in differing regions of the sub-continent.

In a study of this kind, it is inevitable that many more possibilities for research should suggest themselves. These are mainly particular projects, mentioned in the appropriate chapters or appendixes, in which the relations of a particular disease, for instance, might be further studied in relation to climate, using the concept of 'climatic years' with criteria chosen for their relevance to the pathogens concerned. Such studies may well be worth undertaking in future, as a contribution to knowledge, in the hope of producing useful forecasts, and to clarify the task of preventive medicine in differing regions.

Not all possibilities for future research are concerned with only one disease. Thus research devoted to the seasonal and yearly variations in the area within which are found climatic conditions suitable for the multiplication and activities of the house-fly would have implications for several intestinal diseases. Rather similarly in the case of mosquitoes, in so far as the different species have common requirements which can be mapped together, light would be thrown above all on malaria but also on other mosquito-borne diseases. Perhaps no such study would have wider implications both for health and disease than a comprehensive view of seasonal and annual variations in the water-table, the varying means of drawing water from it, and the degree to which well-water is used compared with surface water. Of somewhat similar scope would be the studies of nutrition related to agricultural geography, and of habits and customs affecting health and disease, suggested at the beginning of chapter 12.

The present study is avowedly general in scope, but differs from such a work as Kingsley Davis' book on the Population of Indo-Pakistan in its interest in regional differentation. Even although so much of the work done has concerned only the main headings especially of mortality in the annual public health reports, yet some picture of the regional differences in health and disease emerges. Even at this stage the maps analysed in chapters 2 to 11 give some quantitative basis for regional differentiation, which the writer hopes in the future to reinforce both by further statistical correlation and by more sample studies.

On the broadest scale, the chief zones of Indo-Pakistan might be outlined; first, a pluviose, tropical and rice-eating zone might be distinguished, associated with severe endemicity of several diseases. These are mosquito-borne, fly-borne and water-borne - malaria, filariasis and cholera and other intestinal diseases. Chronic malnutrition results from the inadequate diet based on rice, or on rice-and-tapioca in the South-west. Poverty and backwardness are linked to diseases such as leprosy and smallpox.

In contrast, one might distinguish a zone of semi-arid conditions and variable rainfall, the northern half being continental and millet and wheat-eating, the southern half mainly millet-eating. This great zone is associated above all with instability and fluctuations in its conditions of economy, health, nutrition and disease. Great variations occur in harvests, bringing alternations of relative plenty with lean years or actual famine, often accompanied by epidemics of disease spread by insects, water and man himself. Malaria, plague, intestinal diseases and influenza may all strike in this fashion. These epidemics typically spread from endemic centres outside the area or within it, notably the latter in the case of plague which spreads from urban centres or large villages, and malaria which is maintained in wet and forested hill and hill-foot tracts within the zone. In the northern half of this zone, pneumonia, measles and influenza, for instance are probably more important in the cool season, especially during a famine.

Still thinking on the broadest scale, one should overlay upon this outline one disease which is certainly of great present and potential importance - tuberculosis - also one interesting possibility, namely that the intestinal diseases may be even more important in peninsular India as a sub-stratum to the paramount problem of malaria than in the northern plain, presumably because of different conditions of the water-table.

The few Himalayan Districts afford glimpses of a far from favourable picture, with a depressing complex of low standards of material life and health, poor nutrition, liability to severe epidemics of cholera, to endemic or epidemic malaria, and to diseases of poverty, backwardness and ignorance like leprosy and osteomalacia.

Within these great zones, there are, of course, regional differences of the utmost significance. To consider only the plain-lands of north-eastern India, fundamentally different problems are found in the dying delta of West Bengal, whose population is in the state termed 'stagnation' the active delta of East Bengal with its high natural increase in population until 1943 and in the colonisation tract of the Assam valley. So far as these problems can yet be described and delimited, the present writer has tried to contribute by syntheses of differing orders in Chapter 11 on population change and in Chapter 12 on village studies. Thus statistics are used to give some general account of British India, and local, sample studies are made. The correlation of such local studies would, in time, give a much more accurate picture of the whole. Geddes' work of 1942 remains of great significance, but the present essay shows firstly further interactions between the physical and cultural environment and the state of health and disease which is largely summed up in the state of demographic change, and secondly some modification of the trends in recent years.

Such differences as those cited in the preceding paragraph, and elsewhere in this essay, may well be considered in ecological terms, as evidence of differing states of adjustment or equilibrium between groups of men and their environment; and in a sub-continent in which the greater proportion of the people still largely depend on the food they themselves produce from the land, or at least on food produced near their homes, there is still much justification for this point of view. One view of the unfavourable extremes of population stagnation and recurrent crisis might be that they represent different varieties of the Malthusian checks on population growth, and that they therefore do represent a state of unstable "equilibrium" or of oscillation, more or less violent according to the climatic and biotic complex involved. On this view, if disequilibrium has arisen, it would be because of a number of new factors. Thus during the later British period famines have been prevented, many outbreaks of epidemic disease have been checked which might have spread as pandemics. Craft workers were ousted by competition from large-scale manufacturing industries in Britain, India and elsewhere, and this had driven yet more people back to the land. Cash cropping has been increased.

All these new factors had operated without major steps - except the great irrigation schemes - to increase the amount and flow of food supplies through increased areas or yields - or to pave the way to a higher standard of living and a new state of equilibrium given the more or less limited natural resources of the land.

The present writer's review of the medical literature and statistics leads him to lend some support to such a view. Western medicine, and its many devoted servants in India, both European and Indian, have accomplished great work especially by acquiring basic knowledge, notably of pathogens and nutritional diseases. They have prevented the spread of many epidemics and have saved many individual lives and much individual suffering. Yet though the literature has been written mainly by doctors trained in curative rather than in preventive medicine, it reiterates the theme of the vicious circle of poverty backward agriculture and malnutrition, ignorance poor environmental hygiene and disease. It might be argued from this that from any practical point of view geographical studies of these problems must be futile, since on the one hand man can not alter the regional differences of climate, while on the other hand the social and economic elements are factors very largely common to the whole sub-continent.

There are nevertheless sound practical reasons for pursuing the geographical study of health and disease. The new governments of India and Pakistan, and all men of good will, are rightly dissatisfied with the type of "equilibrium" or disequilibrium described in this essay. Remedies are sought. Thus schemes for improvement have been started under the Colombo plan under the five year plans for the new states, and in detail under various irrigation projects together with the great plan for village improvement in India called the 'key village' scheme, and the land gift movement to help to assuage land hunger. It is of great importance, the writer believes, that all possible support be given to the new governments in their determination to advance by comprehensive planning, by 'bonification integrale' which is ultimately preventive medicine of the most far-seeing kind, rather than repeat the expensive experiments mainly in curative medicine of the British period. The virtual outlawing of malaria, for instance, by the use of the residual insecticides, must go on; this is an essential preliminary step before educational standards can really improve in malarious areas - and without better education improved standards of material life cannot be realised. But this anti-malaria campaign will be wasted if it is not accompanied by comprehensive plans for the improvement of the land, the agriculture and the local industries. In fact, plans must aim at a new and more satisfactory state of equilibrium of the community with the resources of the land. This can only be attained by relation to differing regional environments and resources.

It is in the survey work preliminary to planning for this new phase of ecological equilibrium that a geographical conspectus seems so urgently needed. To this, the present study has sought to offer certain pointers, but the great challenge should and can be met mainly by Indians and Pakistanis themselves.

The writer is convinced that the new Governments should maintain before them the vision of preventive medicine in its widest sense. They should encourage some among their best young minds to train for geographical survey linked to preventive medicine and to planning. Pilot surveys would help to serve this end, and at the same time provide data of fundamental importance for scientific geography and social medicine. Such surveys should be regional and extensive in their general plan, but local and intensive in their application to sample communities of village, town and city. And team-work is probably essential.

Only a team of workers from complementary fields of study can adequately investigate the inter-relations of place, work and folk, from the physical nature of the environment, through the activities of man, to his survival or non-survival, his health or disease. Thus the ultimate manifestation of these inter-relations may well be expressed in the mental outlook of a community, of which any plan must take cognisance. Geddes' work in this field has been corroborated by administrators, doctors serving several branches of medicine and notably by a psychiatrist (Hyatt Williams 1950). But only field survey by a team including a geographer and a social psychologist can follow such pioneer work by the massing of the detailed evidence required both for scientific and for practical purposes.

This essay in medical geography is in a sense also an essay in historical geography, since its data and findings apply mainly to the closing decades of the British period in India. But it concludes with suggestions for possible future development of studies in medical geography in the sub-continent. The dynamic and challenging nature of the problems encountered is emphasised, and the writer has sought throughout to contribute an approach, method and findings which may be useful in further work in India and Pakistan. There have been some great advances since the close of the period studied, but many problems remain for solution. This essay may be found of some value in so far as the problems of Indo-Pakistan - and perhaps of the Tropics as a whole - are ecological rather than political.

APPENDIX A.

Malaria - A review of some of the medical literature from a geographer's point of view.

Malaria is a disease in which the blood of man is invaded by protozoal parasites, namely certain species of Plasmodium; these parasites are transmitted by the females of certain species of Anopholes mosquitoes, which in fact are alternate hosts, both man and mosquito being essential for the full life-cycle of the plasmodia. The degree of symbiosis attained between man and parasite varies greatly; a considerable degree of adjustment to the presence of the parasite is found in human groups long indigenous to certain 'hole-endemic' areas as defined below; there is therefore a lack of marked and overt symptoms of disease ~~found~~ - at least in those who survive to adult years. At the other extreme are acute and sometimes fatal attacks of the disease, especially in children or in newcomers to a malarious area, who have not developed such immunity. But the presence of the parasite is normally associated with a chronic state, characterised by intermittent and remittent bouts of fever, with enlarged spleens, with anaemia and often with weakness, lethargy and irritability. The distribution of malaria in India has been portrayed in a remarkable piece of cartography by Christophers and Sinton (1926) Figure 21 in the preceding essay is a black-and-white version of a later issue of this later coloured map, (Malaria Survey of India, published in All-India Health Report 1940). An annexure to this Appendix reproduces the original accompanying text by Christophers and

Sinton, modified only where changes are necessitated by the use of the black-and-white version instead of the coloured map. This map is in itself a remarkable synthesis (as also is Hehir's regional treatment, which is also included in the Annexure to this Appendix). It may be unusual to follow such a synthesis by material more analytical in nature, but this order is adopted because the map may be referred to frequently in the forthcoming discussion. It will be seen that malaria is present in some degree and in some form in almost all inhabited parts of India under about 5000 feet, including a relatively dry central and north-western area mainly subject to occasional, or epidemic malaria, and more pluviose coastal and mountain and plateau areas of various degrees of endemicity. Christophers based the concept of 'hyper-endemicity' on evidence from certain of these endemic areas (see p. 125). But none are now regarded as achieving that considerable degree of symbiosis between parasite and human host, for which the term 'holo-endemicity' has been coined after reviewing the evidence from malarial areas in all the continents (W.H.O. 1951).

Before discussing the distribution of the disease in India in more detail, and the various specific problems raised, a very simple description of the nature and life-cycle of the plasmodium will be attempted (mainly based on Field Service Hygiene 1945 pp. 293-294.)

The species of Plasmodium causing malaria in man are:-
(a) Plasmodium falciparum, which causes malignant tertian (M.T.) or sub-tertian fever (Tertian etc. refer to the number of days tending to intervene between attacks of fever - see also below

on this page.

(b) P. vivax, causing benign tertian fever (B.T.)

(c) P. malariae, causing quartan fever.

(d) P. ovale causing a self-limiting and mild form of tertian fever.

The first three, but especially P. falciparum and P. vivax, are widely distributed in India, but P. ovale is almost confined to tropical Africa.

The life cycle of the plasmodium may be summarised as follows:-

(i) The asexual cycle in man (schizogony)

As an infected female mosquito is in the act of biting a man, sporozoites from its saliva pass into the human blood stream. They then vanish from the circulatory system for a time, and it has recently been discovered that a phase of development takes place during which the parasites are in the liver (Shortt etc. 1951). Next, both asexual and sexual forms of the parasite appear in the red blood corpuscles, from which they absorb both nutriment and haemoglobin. In the case of the asexual forms, a series of developmental changes takes place, after which the parasite multiplies by asexual segmentation or schizogony. The new individual parasites now attach themselves to fresh blood cells, where the asexual cycle of growth and segmentation begins anew. The asexual cycle is completed in 48 hours in P. falciparum, P. vivax and P. ovale, and in 72 hours in P. malariae, thus accounting for the different periodicity of fever mentioned above.

The sexual forms, male and female, remain within the corpuscles until taken up by a female mosquito sucking the blood; failing this, they degenerate and die.

(b) <u>The sexual cycle in the mosquito</u>

The male and female forms mature in the mosquito ready for fertilisation, which takes the form of union in a new entity which enters the stomach wall of the mosquito, where it changes again to form an oocyst. In this oocyst, the chromatin or protoplasm derived from the original male and female protozoa divides into particles each of which ultimately forms a sporozoite. Finally the wall of the oocyst ruptures, releasing a large number of sporozoites into the body cavity of the mosquito, whence they invade its salivary glands, to be discharged along with the saliva if the mosquito bites a man, and so the whole process starts anew. It has been shown that if the mosquito's proboscis is inserted into the human skin for as little as fifteen seconds, sporozoites may be injected.

The life-cycle of the malarial mosquito may be outlined more briefly, at this stage. It includes the laying of eggs on water, hatching to larvae swimming and feeding in the water; the quiescent pupal stage is also spent in water, but on the emergence of the perfect insect it crawls out of the water to dry on some convenient perch before flying off to its adult career of sucking the sap of plants, or in the case of the females, the blood of humans (sometimes of cattle), mating, and egg-laying. The varied requirements of some important species of Anopheles are dealt with on page 108.

This brief outline of the life-cycle of the guilty species of protozoa and mosquitos is necessary before considering the requirements of human malaria. These are:-

Firstly, a reservoir of patients or immune carriers in whose blood the sexual forms of the Plasmodium are to be found.

Secondly, mosquitoes of the several species which are alternate hosts for the variety or varieties of plasmodium concerned.

And, thirdly, a population of susceptible people who may be infected with the sporozoites on being bitten by the mosquitoes.

The second item in particular implies conditions of temperature and humidity suitable for both the plasmodium and the mosquito.

In considering the relations of climate and malaria, it is particularly necessary to consider not only influences on the plasmodium and on the mosquito, but also effects on man, directly on his vitality, and indirectly as through the good or bad harvests brought by the vagaries of climate.

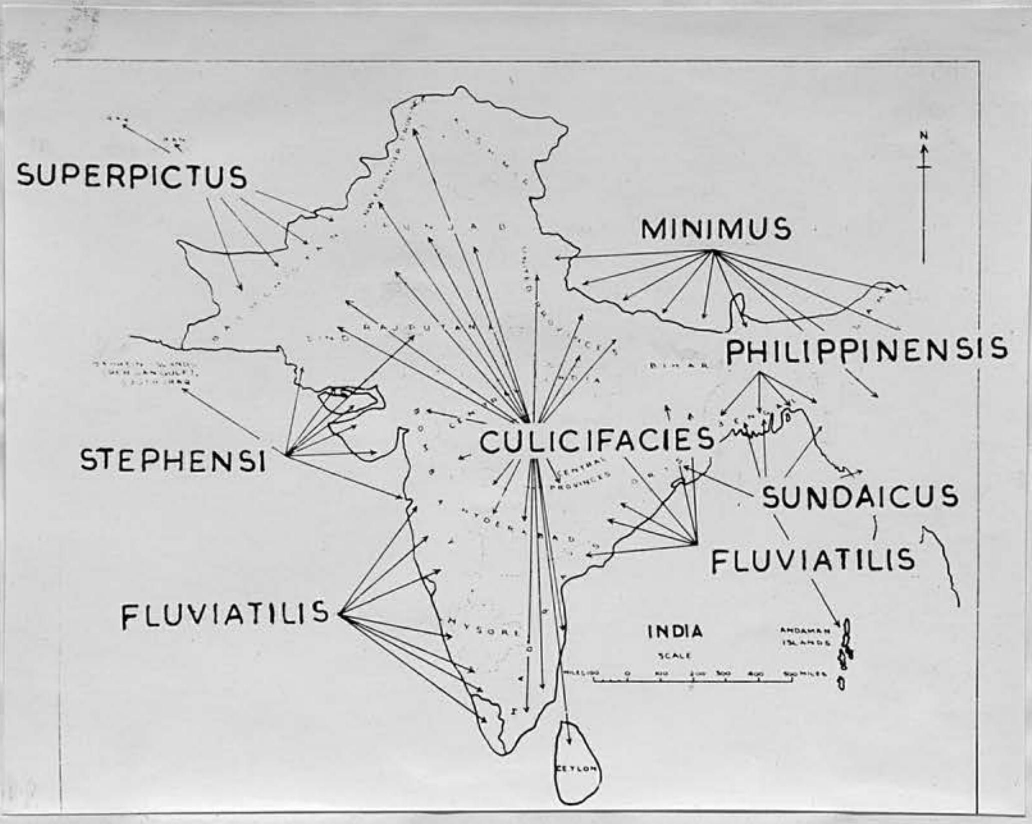
In the case of the plasmodium, the only evidence concerning climatic influences shows that temperatures are of importance. Firstly optimum and secondly minimum temperatures for the development of the sexual cycle of the three chief species of plasmodium in the mosquito, are as follows:-

	Optimum	Minimum
P. vivax	25°C (77°F)......	17.5°C (63.5°F)
P. falciparum	30°C (86°F)......	18°C (64.5°F)
P. malariae	22°C (72°F)......	16.5°C (61.5°F)

Above these minima, temperature governs the time taken for the sexual cycle of plasmodium to be completed, and therefore the time taken for the mosquito to become infective after the sucking of blood from a man who has sexual forms of plasmodium in his peripheral circulation. It may be in this fashion that the lower temperatures of mountain regions in India hinder transmission there. The sexual cycle normally takes ten or twelve days, but if is slowed down by unfavourable conditions, the plasmodium may be dormant for several months. Once infective, a mosquito may be so for up to two months. (May 1951, Hehir 1927 and Field Service Hygiene 1945). In north-eastern India, some very broad climatic relations of infectivity in A. stephensi (the vector of the malignant form of malaria called blackwater fever) have been expressed by Strickland (1933a): he found that infection increased as the night minimum temperatures rose above 60°F, and then was encouraged by rains or high humidities; again very high temperatures had an inhibiting effect. The same worker was able to give some more quantitative data concerning the infectivity of A. stephensi after a year's laboratory observations: (Strickland 1933b).

	Temperature	Relative Humidity
Mosquitoes became infected	62-96°F	32-85%
Optimum range	62-87	32-43 (4 pm)
OR expressed as monthly means	71-76	66-70

As maximum temperatures mounted over 81°F, OR minimum temperatures fell below 66°F OR as relative humidity rose over 43% (.4 p.m.), the infection rate fell remarkably. Strickland notes



39 Geographical distribution of the vectors tabulated in figure 38....................

The chief vectors of malaria in India as mapped by Covell (1949) - some ecological relations.

Fig. 38.

Name of mosquito Type of water preferred for breeding.	Feeding habits etc.	Distribution and importance.
Anopheles minimus Still water of rice-fields or dead river stretches. More rarely running water. Especially clear, unpolluted slowly-moving water with grassy edges.	Vegetation/micro-climate Does not breed in jungle giving complete shade, but partial shade, patches of sun shin'g. through, no deterrent. Feeding. Recorded Assam & Bengal as domestic; rests in dark rooms near earth floors, under bamboo beds, under tables etc. Most of adults in lower half of room. Feeds after midnight. Rarely over $\frac{1}{2}$ mile from breeding place.	Chief vectorfo[illegible] U.P., Bengal, Assam & one of two chief vectors Singhbhum & Jeypore Hills.
A. fluviatilis Similar to A. minimus	strictly domestic, breeds immediately near houses, precautions within 500 yards suffice; N. Kanara recorded as feeding 1st $\frac{1}{4}$ of night, beginning within $1\frac{1}{2}$ hours of dusk, but Satpuras, later, about 2 A.m.	Throughout India but 2 distinct biological races. S. Indian race strong preference for man, N. Indian race feeds mostly on cattle. Chief vector W. Ghats, Mysore, Travancore, E. Ghats, Jeypore Hills, Singhbhum hills, Satpuras; foothills U.P. great numbers but not a vector, nor anywhere E. of peninsular India.

A. culicifacies All kinds: fresh clean water, sluggish streams often with sandy margins, sheets of fresh rain-water, irrigation channels, rice-fields, borrow-pits, shallow wells, pools, river-beds, ornamental & swimming pools, occasionally brackish water.	Nocturnal and inside buildings. Normally dominantly cattle-feeder, but epidemic years turns largely to humans. Range $\frac{1}{2}$ mile, 1 mile exceptional. Hides in dark corners, crevices, thatch.	All India under 3000 feet, but importance as a vector chiefly Punjab & N.W.F.P.; not a vector in E. India & not important in Satpuras, Chota Nagpur, Jeypore hills, nor E. coastal tracts N. of Godavari. In nature sporozoites in about 5-10%, but low rate of .11% found in area with spleen rate 30-40%
A. stephensi River-bed pools, back-waters, irrigation channels, seepage and leakage pools, small artificial water-bodies, waterjars, fire-buckets, water cisterns, wells, roof-gutters, cellars into which water has percolated, tin-cans & other receptacles in rains, hollows in machinery, scrap-iron etc.	Cities, adults remain close to breeding place. Often in cattle byres. Rural areas range up to $1\frac{1}{2}$ miles in open country; equally common houses & byres.	Almost universal. One of chief vectors & especially important in cities. About 3-10 per cent may carry sporozoites. Effective vector in rural W. & NW, not E & C. India nor Punjab/U.P. though responsible Lucknow outbreak 1929. Cities especially Bangalore, Bombay, Poona.
A. philippinensis Tanks, pools, borrow pits, ditches - clear water, with marginal vegetation & dense growth of sub-aqueous bushes (Hydrilla verticillata, Certophyllum demersum & certain species of Utricularia & Najas). Even slight contamination repels. Not in villages where water-table is low. Does not favour rice-fields nor silt-laden water.	Adults confined to human habitations within $\frac{1}{2}$ mile of breeding place. Prefers houses to cow-sheds. Rests about $1\frac{1}{2}$ feet from floor bedrooms & kitchens & also on pots etc. on floor. Feeds chiefly 2-4am. but to some extent also 8-10 p.m. (Andamans probably have "wild" variant of this mainly domestic species).	E. & peninsula India. Chief vector of S. & W. Bengal (dying delta).

A. sundaicus Saline water, usually but not always in presence of algae. Lagoons thro' blocking of river mouth by sand-bars. Behind embankment to protect paddy from sea. Borrow pits, hoof prints. Any water collections in cleared mangrove area where daily action of tide impeded by embankments for roads, railways etc.	Adults rest in houses & cattle sheds. Voracious feeder, known to feed in day as well as by night. True house mosquito & will bite man even in presence of cattle.	Coastal Arakan, Bengal, Orissa, Andamans & Nicobars. An important vector in these areas. Outbreaks tend to be erratic - appear & disappear up & down coast according to local conditions.
A. superpictus Running water exposed to sunlight, especially along edges of streams where dense masses of spyrogyra ; retard stream flow. Also seepages & marshy areas, open irrigation channels, reservoirs, pools, wells, springs, sub-soil water in cracks & fissures and in tunnels of Karez irrigation.	Adults rest in outdoor resting places such as karez shafts & tunnels, and caves.	An E. Mediterranea species which occur in India only in Baluchistan & N.W. F.P. Not recorded east of Indus. Important vector locally.

an apparent contradiction with Gill's finding of a correlation with <u>high</u> relative humidities in Punjab in July, but notes that in fact the humidities involved in Bengal (where mid-November to mid-January are most favourable) correspond remarkably with those quoted by Gill in Punjab.

Since most of the rest of the discussion is really centred on the activities of the mosquito, a further selective account of its bionomics will be given before continuing the analysis of the environmental relations of malaria. Since the writer has been unable as yet to work on more recent authorities, such as Marston Bates (1949), the source for these paragraphs is mainly Hehir's general text-book on Malaria.

The factors influencing the dissemination of malaria by anopheles include the species of anopheles, their geographical distribution, their numbers and habits, the circumstances promoting or retarding the development of the parasite in the insect, the length of life of the anopheles, their rate of multiplication, their distance of flight, the nature of their ordinary food supply, the kinds of water in which breeding takes place, and the nature of their hibernation and aestivation.

Figure 39 is a map of the geographical distribution of the main vectors of malaria in India, and opposite this page is a table compiled to throw some light on the kinds of water used for breeding, the feeding habits of the adults and on distribution and importance, species by species. Fig 38 The following discussion will complement the map and table with a more general discussion of some of the factors mentioned above.

The food of mosquitoes in general is not the blood of man or other animals. All males are vegetarian. But the females of some species of certain genera suck blood; and in some this favours ovulation although it is not essential for fertile oviposition nor will fertile oviposition take place in the absence of copulation with the male. For the rest, the food is found in vegetable juices - many species prefer that of ripe bananas, for instance. Among the species whose females do suck blood, some prefer that of cattle, and some that of men, but these preferences are not necessarily consistent in the same species as between one part of the world and another. A female when feeding will gorge up to five times her own weight of blood, usually from several persons and she is more avid for blood in warm damp weather. At the larval stage (in water) the anopheline larvae are normally surface feeders, eating protozoa there, whereas other species of mosquitoes often consume organic particles on the bottom. Large species are often predatory and cannibal.

Fecundation takes place soon after theemergence of the adult form from the pupal stage, and a virgin female is seldom found. A swarm of males may be seen dancing above a pond. When a female arrives, there is rivalry and fighting among the males, then the female goes off with a male to mate. They separate, and the female goes off to seek a quiet place for safe laying of the eggs, with a supply of food nearby. Once this is found she probably remains close to it. Two or three generations are commonly bred between the rains and the cool weather in northern India, and in this time one female can produce $7\frac{1}{2}$ million descendants; so long as favourable conditions last, the increase is in geometrical progression.

Hibernation and aestivation take place in outhouses, bridges, ruins etc. Sixteen anopheles have been found in one straw in a thatched roof. The climatic relations will be discussed more analytically presently, but meantime it is worth noting Hehir's belief that hibernation takes place only north of about Agra, and that mosquitoes do emerge on warm days within the cool season. The mosquitoes do find dry heat hostile, so that in a typical monsoon climate there is a Spring increase after the cool weather, then a hot weather decrease, in which some successfully aestivate, but many die. Besides hibernation proper, there is a spring hatch of eggs which have remained fertile in damp mud through the cool season and hatch with the increasing temperatures.

The mosquitoes' length of life is probably usually about one to two months. It has been proved that they can infect human with malaria two months after themselves being infected, and it is possible that infection may survive in the mosquito through the cool season, when the mosquito's metabolism is at a low level.

There is some evidence that if mosquitoes are relatively few in number in a malarious locality, then the percentage of them infected with malaria may be higher. It is believed that some strains of mosquitoes become immune to malaria, probably through hundreds of generations of selection, and do not carry it;

but there may be quite local peculiarities in this matter. To this a further possible factor should be added which Hehir suggests may account for some otherwise inexplicable local variations in malaria. Some towns may be relatively free because of the dominance of Anopheles subpictus, which not only is not a vector of malaria, but also seems to have some power of excluding other malarial mosquitoes. An example is the area of salt lakes just east of Calcutta, where the settlements are fishing villages on plinths just above the water. Very little agriculture is carried on, so that there are very few cattle indeed, and the great numbers of A. subpictus breeding in the brackish water must therefore be anthropophilous, yet they do not carry malaria. This area is in fact held to be a screen for the city, the draining of which would adversely affect the situation there. (Iyengar 1931).

The adaptability of the mosquito has important implications. Thus if the ecological conditions preferred by a particular species are not exactly met, it may breed quite successfully in other types of water bodies, so that in practice almost any collection of water is suspect. A species has been known to change its habits and adapt itself to new conditions, e.g. the adaptation of Anopheles stephensi to cisterns and wells, to make it the only species which is a serious threat in large built-up areas. There are adaptations to different environments apparently within the same species. In time, some workers believe, strains may be evolved resistant to D.D.T., so that a return to biological methods of control may yet be necessary. (White 1948).

One characteristic, however, does seem to be universal, and is certainly of paramount importance, namely the limited range of flight of the anopheles. The effective range in India is generally about half-a-mile, unless the wind is blowing. With a wind, recent work in the Philippines suggests that the range is 600 to 2000 metres, mainly in the direction of the prevailing winds except for eddies (Ejercito etc. 1951). Mosquitoes are weak fliers and a strong wind inhibits their activities. One important consequence of this relatively restricted range is the inability of most species to penetrate large built-up areas. Moreover, it is because of this that Hehir again and again urges that malaria, though widespread, is yet a local disease, in which quite local preventive measures are worthwhile. The whole cycle between mosquito and man may take place within the compass of a hundred yards.

There are cases of mosquito migration, however. In epidemic years, one important factor may be the great increase in the anopheline population, due to exceptionally favourable climatic conditions, but outstripping the food resources of the locality. Thus the anopheles are forced to move out in a 'swarm' after the fashion of locusts, moving in this case against the wind (i.e. contrary to the normal direction of movement of anopheles). There is also a more gradual infiltration of the new generations of mosquitoes, most of which move off at right angles to their parents' route between breeding place and source of food. But this is a very short-distance movement - a journey to the next village would be exceptional. It should perhaps be noted here that malaria is not hereditary in mosquitos and that the malarial potential of these new generations will depend on conditions in their new locale. Added to these journeys are accidental movements by boat, train etc. into entirely fresh territory.

The known climatic relations of the anopheles are complex. A general account will be attempted, but wherever figures are quoted, there is the likelihood that they have been derived from laboratory work on certain species; yet they may give some guidance as to the behaviour of anopheles in general under natural conditions.

Excessive rainfall may favour malaria through increased stagnant water permitting greater anopheline numbers and activity especially in the drier areas: thus heavy rains in Punjab were one of the chief positive indexes used by Gill in forecasting malaria (see p. 116). On the other hand, an epidemic thus caused by excessive rain is worse if it follows a year of drought or especially a sequence of drought years. Excessive rains, however, reduce malaria by flushing the water-courses free of larvae, for instance in the hill-foot or terai zone. And again drought in a normally pluviose area causes excessive malaria by providing more stagnant or gently-flowing water bodies, as in south-western Ceylon in 1935. (Mainly Field Service Hygiene 1945).

Before considering temperatures in relation to adult mosquitoes, it is relevant to note the inhibiting effect of high water temperatures on the larvae. At 20°C (68°F), larvae die in two days, at 35°C (95°F) in one day, and at 40°C (104°F) in two minutes.

The effect of altitude per se in eliminating malaria through lowering temperatures is thought not to take effect below about 6500 feet. The evidence lies partly in small temporary epidemics brought in by troops moving in to hill stations from endemic areas, and partly in that high plateau country in Baluchistan may be malarious, in the presence of sluggish streams, while Himalayan hill-country at comparable heights is malaria-free, but more because of rapid run-off on steep slopes than because of temperature (Field Service Hygiene 1945).

It is advisable to interweave a discussion on temperatures with frequent references to relative humidity. To take first the broadest relationships, almost all India falls within the world temperature zone indicative of malarial mosquitoes, since most areas have a minimum monthly mean temperature over 16°C (61°F). (May 1951). In Punjab, this marginal or crucial temperature seems to have relations with relative humidity; it has been found that when the mean monthly temperature does fall below 61°F, malaria is not transmitted if the relative humidity is below 63%. At the other end of the scale, very high temperatures with low relative humidities are inimical to the mosquito and therefore to malaria.

Thus already the discussion has turned towards the seasonal incidence of malaria, as dictated by the seasonal controls of anopheles, a topic which merits some further examination. The areas of longer and ampler rains, approaching more nearly equatorial conditions, may be envisaged as liable to malaria at any time, whereas polewards the incidence becomes more and more seasonal AND IN TROPICAL SUMMER-RAIN CLIMATES the incidence is mainly in the later weeks of the rains and the early cool weather. So long as the tropics are under discussion, the main control is clearly rainfall and humidity. It should be added that the increase in variability of rainfall, is linked with the change from endemic to epidemic conditions. Thus in Central India and the Indo-Gangetic plain, the season is mainly from July to November, with a September maximum, and a secondary peak in April and May due to relapses, and primary infections apparently delayed in onset by the higher resistance of the people during the cool weather. In Southern India, the 'foothills' (presumably the lower slopes of the Western Ghats, for instance) have a maximum from February to June (presumably with a fall during the heavy rains), whereas the main plateau surfaces and coastal plains have a maximum in autumn if they receive the summer monsoon, or spring if they receive the cool-weather rains. Assam (and probably East Bengal, the area of the 'active delta'), have a distinctive regime: malaria is high from March to June, with a peak in May, it falls during the monsoon, and rises again from September to November, with a peak in November. (Mainly Field Service Hygiene 1945). Even in W. Bengal, a fall in the spleen rates has been noted during the monsoon and an attempt has been made to relate this to variation in the 3 important kinds of plasmodium. (Iyengar 1932). The spring peak in areas subject to the normal summer monsoon and to a fairly well marked cool season has received some additional study. Hehir was dissatisfied with attributing this simply to relapses, and thought that the breeding of hibernating mosquitoes was the main factor. (1927). Ramsay has studied the spring peak in Assam (1930). He found that the main vector, A. minimus, has a relative off-season in the cool weather, and since humidities are high enough, this must be due to the fact that night minimum temperatures often fall below 60°F. The mosquitoes do linger on, in cow-sheds etc., with greatly decreased activity but living much longer than at warmer seasons and renew their normal activities in March with the rising night temperatures. The same author, however, points out the probable importance of a human factor, namely the inflow of seasonal labourers and craftsmen (see p. 124 and compare the Appendix on cholera p. 159).

Under the particular conditions of the Punjab, a successful attempt has been made to use the evident relations between climate and malaria, for forecasting epidemic conditions in particular parts of the province (Gill 1927). The method is the result of statistical analysis of past data for various climatic elements and for malaria. It consists of considering together several factors: (a) the rainfall factor - for instance a July rainfall of much over 100% of the average for a District is indicative of severe malaria in the following autumn (b) the spleen factor - thus low spleens in June are suggestive of low immunity, and if other conditions are present, are indicative of severe malaria in the ensuing autumn (c) the potential epidemic factor - a past history of repeated epidemics is indicative that the area will again be visited when conditions are suitable and (d) the economic factor - an attempt, abandoned after the first few years, to allow for the fact that conditions of famine or near famine lower resistance to the disease. It has since been suggested that the spleen factor is not in fact helpful in producing more accurate results. (Yacob etc. 1947 and Swaroop 1949).

The relations of malarial mosquitoes with vegetation receive some mention in Hehir's general text-book on malaria (1927). Its importance lies in its relations with the ecological requirements of the various mosquitoes (see p. 108) including the provision of some of the mosquitoes food. At the larval stage, some aquatic plants give ideal shelter to the larvae - see for instance see under A. philippinensis on p. 108 and again plants growing on the water margins are important to several species. The author points out with reference to "natural" vegetation in general, that tracts of dense jungle may be malaria-free, whereas areas of little or no vegetation may be malarious; he points out that dense jungle may be impenetrable to the anopheles, and that removal of a strip of such jungle may result in a settlement being exposed to invasion from the breeding place of a vector.

The relations of jungle and malaria in Bengal have been further treated by Iyengar (1930). He opposes the demand then being made for all jungle to be cleared within one mile of villages, on the ground that dense jungle, that is where the vegetation cover is so dense that the ground is completely shaded, contains no malaria vectors, and is rather a protection. Thus in the hill-foot Terai tract known as the Duars, which is notoriously malarial, the innocuous anopheles of pools in uncleared jungle, are replaced on clearing by other species which do carry malaria. In the Sunderbans, again, the mangrove and sundar forests are free of malaria vectors, so much so that the Forestry Department houseboats and launches are moored there to escape from malaria. Areas cleared for rice, on the other hand, are subject to heavy breeding of dangerous vectors in pools of brackish water in the area protected against spring tides. Even the cattle sheds are smoked at nightfall, and given some protection by gauze etc. against the mosquitoes, while this is an area where even the poorest people have some kind of mosquito curtain. The causes of the change are not yet known. Sunlight and shade are certainly important in some way, but small natural pools and clearings resemble the surrounding jungle, as indeed do small artificial clearings without dwellings. When houses come in, malaria and its vectors come in also.

Certain relations between different vectors and the differing character of surface waters are briefly treated in tabular form in fig. 38. It is clear that marshes are not essential although they are in fact often favourable, and level lowlying land, or level impermeable soils or rock at any altitude within the climatic limits of the mosquitoes and the plasmodium are favourable - thus clay over granite is a suitable breeding place.

Again a fluctuating water table is found to encourage malaria - presumably epidemic in form - a constantly high water-table, say three to five feet down, to be associated with high endemicity, and a low water table, say fifteen to twenty feet in depth, to be relatively malaria-free. (Hehir 1927). Acidity requirements are known to lie within fairly narrow limits, but are variable from species to species, and the only work encountered concerns one species only, and in thermostatic conditions (Pruthi 1931).).

In turning to the relations between malaria and the type of agriculture practised in India, one must take count of the great number of cattle kept - approximately one animal for every two people and generally distributed roughly in a similar pattern to the people, even to some extent in the cities, up to the present. Many of the mosquitoes are partly zoophilous, and the table on p.108 quotes an interesting case in A. culicifacies which turns more anthropophilous in epidemic years. On a broad view, cattle-sheds act in part as refuges for mosquitoes, especially in times of hibernation, and possibly aestivation, but there is some evidence that the cattle deflect some of the mosquitoes' attention from humans. Ultimately, the malariologist, even thinking as such, must consider the cattle, under present conditions, as competing with humans for the produce of the soil, without giving a commensurate return in food, and therefore lowering the powers of human resistance to the disease. (Hehir 1927)

The cultivation of rice, and the extension of irrigation largely for that purpose, are popularly associated with the spread or the [illegible] of malaria not only in India but in many countries, including Italy for instance. The broadest and most progressive view seems to be that while malaria has often been associated with these agricultural developments in the past, this need not be so, and that ultimately the improvement of food supplies should assist the reduction of malaria. Much depends on how much water is applied, and under what conditions. Malaria does not necessarily increase with an increase of available water through the year, indeed sometimes the reverse is true. In the 'Old Revenue' classification of paddy land yielding one, two and three crops annually, one-crop land will almost certainly be malarious, there will be less danger in the 2-crop land, while, other things being equal, there will be much less malaria in the three-crop land. (Hehir 1927). There is no doubt that the extension of canal irrigation has often been accompanied by violent outbreaks while the construction works were in progress (see p.124), and ultimately by some endemic malaria. Unusual rains and floods soon after the opening of the Lloyd Barrage in Sind produced epidemics which were carefully recorded (Covell etc. 1936). The authors are in no doubt that the outbreak was largely the result of even this great modern scheme, directly or indirectly, and they mention the general raising of the water-table, producing lakes in which breeding took place at least in the exceptionally wet conditions, and the extension of rice cultivation. On the other hand the canals themselves are less favourable to anopheline breeding than rivers, because of the smoother banks etc. The chief breeding places are found not in irrigation water, but in water which is wasted or is failing to do its job, such as leakage and seepage water, which gathers in minor pools, or in major hollows and causes waterlogging and a whole complex of associated ills - malaria, poor cropping, malnutrition and low economic status. This has been especially so where the absence of silt traps at the barrages had caused the silting of the canal beds, the raising of the embankments has followed, and the whole situation has been aggravated. The solution lies largely in concrete or other locally cheaper forms of impermeable lining for the canals, which would in any case result in smoother flow-sections, less turbulence, and therefore lower maintenance costs. (Henderson 1949).

The extension of malarial conditions as rice cultivation advances upon forest in the Bengal delta has already been mentioned (P. 117). Something comparable has been recorded from the Orissa delta, where the excessive prevalence of the normally zoophilic A. annularis is put down to man's alteration of the deltaic land-forms for agricultural purposes (here however, the most dangerous mosquito is held to be Culex fatigans, carrying not malaria but filariasis). (Hajra 1948).

Much man-made malaria has resulted from excavations such as borrow-pits for railway and road embankments, and from the impeding of drainage by such embankments. The borrow-pits can often be dealt with by breaking down relatively thin barriers between adjacent pits, and as they are usually quite shallow, free drainage can often be provided. It is believed that modern mechanical excavators will produce fewer breeding places. It is not usually difficult to restore more natural drainage to water trapped behind a railway or road embankment, but the total number of such obstructions is now very great. (Hehir 1927 Sinton 1938 and Henderson 1949). Borrow-pits dug originally as a source of mud to built up house-sites, or to make the actual walls of the buildings, are common all over India; in many cases they have passed into use as tanks or ponds; as such they have their own health problems, but do not constitute a very serious source of anopheline breeding, although they may do so if neglected and unused. (Hehir 1927).

The houses themselves often contain dark and ill-ventilated corners giving suitable hiding places for the more domesticated mosquitoes. In work on blackwater fever the curious observation was made that coolie bamboo huts in a Bihar mining camp containing fires (and of course without chimneys) were free from the vector (A. funestus) compared with the smokeless and superior houses of Bengali clerical workers; similar and clean but smokeless huts of tea-garden coolies in the Terai were found to be infested by the vector, so that in this case a rational basis was found for the coolies' preference for living out, in smoky huts in the villages. Siting of houses is seldom done having regard to the proximity of breeding places and even in the 1920's mining camps in Singhbhum were found to be badly sited; again a promising sugar plantation in Assam on an island above marsh and flood-level was eventually abandoned because the initial siting both of the bungalows for the supervisory staff and the

...eolic lines was carried out on a malarious peripheral site in order to leave the fertile centre of the island as unbroken stretch of cultivation. (Christophers 1925 and Sinton 1936).

Hehir's general text-book gives some account of factors connected with the general way of life in India, which he found to be associated with malaria. The fact that it is overwhelmingly a rural problem need hardly be stressed further. The incidence in males may be a little more than in females, on account of the men's work exposing them to additional risks while working near breeding places at dusk or dawn - additional to the equal risks to which the whole family is exposed from the generally nocturnal and domestic feeding mosquitoes. Race has sometimes been held to be a factor in relative immunity (q.v.), chiefly from the descriptions of relatively healthy aboriginal children in some parts of the Terai, compared with the sick and puny children of recently arrived families of colonists of "Aryan" race. Examples are known of Aryans enjoying considerable immunity, presumably after several generations stay in an endemic area, but there is no record of Europeans nor Eurasians acquiring such immunity.

There is a general association of malaria with poor general health, with the terrible vicious circle of poor education, poverty, squalor, poor food and malnutrition - especially marked after crop failures in two or more successive years - and of course with a general lack of treatment, knowledge or equipment for prevention of the disease, in such a predominantly rural problem. Particular attacks are associated with any factors which lower resistance - chills, excessive heat, or wetting, a fast, fatigue, worry, strain, menstruation, pregnancy, a wound or surgical operation, or previous attacks of malaria.

Movements of population may be an important factor. Immigration of infected people is thought to be important although Hehir knew of no exact observations, and the present writer has encountered none. The continual inflow of susceptible labourers, colonists and seasonal workers into Assam (itself caused largely by the failure of the labour force to maintain itself because of malaria), is suspected of causing the disease to flare up not only among the new-comers, but among those already resident in the area. (Ramsay 1930 & Sinton 1936).

A special case involving the factors presented in the preceding two paragraphs is found in the epidemics associated with gangs of coolies employed on major engineering projects - "tropical aggregation of labour" has been an important cause of killing epidemics in the past, in connection with the construction of roads and especially railways and canals, but need not arise in future, as is shown, for instance, by the almost completely malaria-free irrigation schemes in the Dry Zone of Ceylon, in recent years. (Hehir 1927 et al).

Finally, some review will be attempted of the material, in itself a considerable literature, dealing with the interrelated topics of congenital malaria, infantile malaria, immunity and hyper-endemicity or holo-endemicity, and epidemicity. In the course of a classic malarial survey of mining communities in Singhbhum in 1924, Christophers first identified and described the condition of hyper-endemicity of malaria in a community:- this is a sort of saturation point of malarial infection, in which the survivors of almost incredibly severe and sustained attacks of malaria in childhood possess during most of their adult life a state of relative immunity, attacks being relatively mild and infrequent. The stages towards this state of relative balance may be summarised as follows:-

1 - 2 years	..	sustained and extraordinarily intensive attacks of malaria
2 - 5 "	..	fewer parasites, attacks now only 1 in 25 days
6 - 10 "	..	infestation does not amount to attack, state of relative immunity.
12 - 16 "	..	one attack in three months.
Adult "	..	" " " six months, but only sick not incapacitated. This only applies to indigenous folk, of course, not to immigrant labour.

Subsequent work on the various ages and stages may now be reviewed. Malaria has long been known to have a marked association with abortions and still-births, which are believed to vary inversely with the mother's tolerance to malaria (Covell 1950); and also with high infant mortality, but less through direct attacks than because the mother is attacked in her time of weakness and is unable to attend to the new-born child. It has now been shown that where a mother has suffered from active malaria during pregnancy possibly 1 to 4 per cent of babies will be borne with congenital malaria, and this may swell the infant mortality rate; the proportion is, however, very low in communities with a high degree of tolerance to malarial infection ('Tolerance' and 'immunity' will be discussed presently). On the other hand, there is strong evidence that a considerable degree of temporary "passive immunity", can be passed from mother to child. This lasts for a few months, up to eighteen months, and at the end of this variable period, the passive immunity is succeeded by the phase of infants' acute malaria. Some workers have said that the total infant mortality due to malaria seems to be less than is usually supposed. (Wilson etc. 1950). On the other hand, remarkable changes in infant mortality rates have been recorded on beginning DDT spraying in both epidemic and endemic areas (Delhi & Coorg - Jaswant Singh 1949 a and b). At this point the modern viewpoint may be summarised in the 'hypothetical diagram of immunity of individuals in hyperendemic communities' of Wilson etc. (1950):-

Congenital immunity	- Passive immunity	- 0-3 months
	Acute infestation	Up to 3 years
Acquired immunity	- Immune infestation	3 years and upwards given a background of racial or group tolerance.

Most of continental India is regarded as of high endemicity with incomplete immunity. Areas where Plasmodium vivax is the dominant type of malarial infection are not truly hyperendemic. (It is as a description of severe endemicity mainly of P. vivax, and short of saturation point that some medical readers find Geddes' work on areas of 'population stagnation' of peculiar interest; but it should be noted that West Bengal, for instance, is mapped by May as having P. falciparum dominant). On the laboratory side, as distinct from epidemiological work, some investigations on the development of resistance to P. vivax, using volunteers, show that complete immunity to this infection resists chills etc. but is only effective against the one type of

Plasmodium: short of that, however, is a state called tolerance, where the subject is liable to relapses from malaria on being subjected to chills etc., but on the other hand the protection is not 'strain-specific'. (Blackburn 1948).

It is important in examining these stages to note that in infancy and childhood, deaths are directly attributable to malaria, which overwhelms the child by intensity of attack; in adult life, except in epidemics, malaria is more of a constant drag on health and efficiency, and deaths in which malaria is concerned are more often due to some proximate cause, such as pneumonia or dysentery, or to some long-term complication of malaria such as much of the cirrhosis of the liver common in the Punjab (Hehir 1927 and Hughes 1927 & 1933-34). An interesting quantitative study has been made of the relations between malaria and other diseases in parts of the District of Murshidabad in Bengal (Brahmachari 1923). The area called Bokhara, was invaded by severe malaria during the period of study, and along with a rise in the malaria death rate of over 400 per cent, there was in the death rate from other causes by 250 per cent.

It would be inappropriate to conclude a review of this nature without reference to the major contribution on "What malaria costs India" by Sinton (1935-36). This long paper is a most thorough analysis of the economic effects and implications of malaria, with a wealth of evidence and example from long experience and from an extensive bibliography. Some of the great wealth of material has been referred to in the foregoing review, but the main themes and findings, and the endeavour constantly ..

[illegible], are perhaps best indicated by quoting Sinton's own General Summary and Conclusions:-

"Evidence has been produced to show that in India -

(1) Malaria by its effects upon the birth rate and on the death rate is a great, and probably the greatest, single cause in retarding the natural increase of the population.

(a) Malaria has a very marked action in lowering the birth rate by (i) reducing the numbers of conceptions, and by (ii) causing interruptions in pregnancy which result in abortions and still-births;

(b) Malaria is, in ordinary years, responsible directly for at least 1,000,000 deaths each year, and, in years when severe regional epidemics occur, this figure may be increased by another quarter of a million;

(c) Apart from this directly mortality, by its indirect action in lowering the general vitality of the afflicted, whereby many of them become more liable to contract other diseases, malaria is indirectly responsible for a very large number of additional deaths;

(d) Malaria by its direct and indirect actions is almost certainly responsible for at least 2,000,000 deaths each year.

(2) Malaria is probably the greatest factor in lowering the health, vitality and physical development of the people, in the areas where this disease prevails.

(a) It is probable that at least 100 million persons suffer from the disease each year.

(b) It is probably responsible, through its effects in lowering the vitality of the sufferers, for an additional indirect morbidity of between 25 and 75 millions annually.

(c) It has a markedly deleterious influence upon the physical and mental development of both children and adults.

(d) It is a very important factor in the causation of the relatively low expectation of life in India.

(3) Malaria has the deplorable effect of hindering greatly the intellectual, social and national development of any people afflicted by it.

(4) Malaria gives rise to the greatest economic problem with which India is faced. The financial losses to the individual and the family alone have been calculated at not less than Rs. 11,000 lakhs annually, or about £80 million sterling per annum. This is apart from the effects of the disease upon all aspects of the labour problem, and thus upon the fullest exploitation of the natural resources of the country and the successful development of her manufacturing and other industries. While it is not possible to evaluate with any degree of accuracy the immensity of these direct and indirect losses, there is little reason to doubt that they must run into unbelievable millions of pounds sterling each year.

(a) The great financial losses to the individual, the family and the community through sickness and death from malaria have been discussed.

(b) It has been shown that malaria caused incalculable losses to agriculture, industry and commerce, mainly through its direct and indirect action upon different aspects of the labour problem. The most important industry of India, namely agriculture, is most markedly affected, and the disease gives rise to a retardation of agricultural development, and sometimes to the abandonment or decline of this work in very fertile, and potentially rich areas.

(5) The financial and economic losses which Governments and administrations have to bear through the effects of this disease have been shown. The disease not only results in a decrease of revenue but also in an increase in the cost of administration.

(6) Having taken these huge losses into account, it has been shown that wisely-planned anti-malarial operations are paying propositions, from which there is often a direct financial profit upon the money invested, and from which there is certainly an indirect profit in the effects which such measures have on the general prosperity of the community.

(7) It has been shown that, apart from all humanitarian aspects of the subject, the benefits which proper anti-malarial operations have upon the social, intellectual and economic progress of the people, make it the duty of every Government and administration to take all steps possible to promote energetic campaigns against this scourge.

"From the evidence available one is justified in concluding that:-

The widespread prevalence of malaria is almost certainly the most serious economic and social problem of India. Others may be considered of secondary importance, in that most of them are directly and indirectly influenced to a very large extent by the protean effects of this disease.

"The labour problem and the malaria problem in India are synonymous, in that this disease is the main cause of the occurrence of inefficient and deficient labour. Through its effects on the labour problem, millions of acres remain uncultivated, or imperfectly cultivated, the natural wealth of the country cannot be fully exploited, and the progress of most industries is seriously hampered. This disease is a great, and probably the greatest, obstacle in the path of the attainment of those national, economic, social and intellectual aspirations, for the achievement of which the huge natural resources and enormous population of India would appear to fit her. At least, one hundred million persons suffer from, and one million succumb to, the direct ravages of this disease each year. What other social or economic problem is there the seriousness of which can be compared with the gravity of these facts and figures?

"The problem of existence in very many parts of India is the problem of malaria. There is no aspect of life in this country which is not affected, either directly or indirectly, by this disease. It constitutes one of the most important causes of economic misfortune, engendering poverty, diminishing the quantity and the quality of the food supply, lowering the physical and intellectual standard of the nation, and hampering increased prosperity and economic progress in every way.

" If India is to obtain the full benefits of that national progress, which she hopes to attain and maintain under her new constitution, the problem of malaria is one which she must tackle immediately by all the means at her command.

"This paper on 'What Malaria Costs India' has been written with the express intention of drawing much more attention to the very grave dangers which malaria places in the way of advancement in all aspects of life in India. The facts and deductions concerning the ravages which the disease causes to this country have been set forth and discussed in detail in relation to sanitary, medical, social, economic and other problems. Unfortunately in the past, the very great influence of malaria upon the solution of these problems has not been sufficiently appreciated by many people, even by so-called experts. Its fundamental relationship to these problems has often been obscured by other issues or glossed over in favour of other interests. It is hoped that the information given in this paper will stimulate a wider appreciation of the importance of this subject among those who have to deal with the many problems influenced by it.

"It is only by a very close, whole-hearted and enthusiastic co-operation between all those agencies which are working for the advancement of the country, whether these be official or non-official, that one can hope to deal effectively with this radical factor in all India's social and economic problems. 'Those who are experts in these matters cannot render the Government, and the cause we are fighting for, a greater service than by keeping the real facts before the public. An educational mosquito and malaria propaganda has a far-reaching value, and in many other directions than merely mosquito and malaria control.' (Hoffman, 1928)."

Annexure to Appendix A - The Malaria Map of India

This annexure is included in order to make readily available the important original text concerning the Malaria Map of India by Christophers and Sinton (1926) and Hehir (1927). The text has been altered where necessary so as to refer to the black-and white version of the map presented as Figure 23, instead of the original coloured map.

<u>A note on the compiling of the map (Christophers and Sinton)</u>

The map has been compiled to display the major epidemiological features of malaria in India so far as they are at present known and capable of being mapped by variations in emdemicity.

The more fundamental epidemiological aspects of malaria distribution i.e. the division of India into tracts where malaria prevalence is liable to be seasonal and epidemic, and those where malaria is more perennial and endemic, are shown respectively by shadings 7 and 8, and by shadings 3 to 6, on figure 23.

Shadings 7 and 8 include all those extensive tracts where, owing to climatic and physical conditions (sub-tropical semi-desert zone), malaria prevalence is markedly seasonal in character, and where malaria endemicity is low or moderate, except when and where special conditions, cyclical seasonal or local lead to its enhancement. A high spleen rate when present in such areas is, as a rule, either the result of abnormally heavy monsoon rainfall (epidemic tracts) or of the existence of special local conditions favouring the disease such as neglected irrigation, water-logging etc.

Within area 7 the black of area 8 indicates the areas in this zone known to be liable to the epidemic malaria characteristic of this part of India (so-called 'autumnal', 'fulminant' or 'diluvial' malaria of Christophers and Gill). These epidemics are pandemic in character, usually occurring at intervals of about eight years and affecting enormous tracts up to 10,000 square miles or more in extent. They exhibit in marked degree a <u>focal</u> distribution, and can be mapped by lined of equal mortality (isothans), when they show contour-like zones of increasing intensity as the centre of the disturbed area is approached. They resemble in a greatly exaggerated formthe normal aurumnal increased prevalence of malaria in these parts, and are displayed in the statistics by a very characteristic seasonal epidemic curve easily differentiated by its time of occurrence and by the shape of the graph from mortality curves due to any other disease. In the heart of the epidemic, villages and small towns are alike visited as by a pestilence, the mortality over hundreds of square miles rising during the prevalence of the epidemic (from late September to December) to 400 per mille or more, so that for this period the death rate may be 10, 20 or even 30 times the normal.

The spleen rate during the epidemic rises from a low figure to 80 or 90 per cent and then gradually falls again through a period of some five years until it once more reaches the normal low figure. The mortality, but not necessarily the morbidity, is preponderatingly among infants, young children and the aged. Should a given tract be unfortunate enough to come within the zone of influence of two or more such epidemics in the decade, the population figure in the next Census may fail to exhibit the normal increase or show a decrease of population.

The epidemics are the result, under such circumastances, of unusual heavy rainfall and there is no doubt that they are largely dependent on extensive diluvial conditions resulting from abnormal rainfall upon river drainage systems normally unaccustomed to cope with such precipitation. From the map it will be seen that the chief site of election for such manifestations is the sub-montance plain of the Punjab, but less extensive manifestations may occur in Sind and elsewhere in zone 7. As a result of knowledge of the causation of these epidemics much attention has been given by the government of the Punjab to the control of flooding in the dangerous areas, and since no major epidemic comparable to those of 1890-1901 and 1908 has recently occurred, this may have had a deterring effect. By the aid of prompt report of meteorological data Gill has been able to make very accurate annual forecasts of liability of particular areas in a given year to this form of malaria, thus enabling early steps to be taken in respect to quinine distribution and other ameliorating measures.

As will be clear, these vast cyclical disturbances form a problem altogether special to this part of India, and it is important that their potential zone of action should be indicated on the map. The areas depicted are such as have at least once shown a mortality of ten times the normal death rate during an epidemic.

Apart from the temporary effect of epidemics of the above character (post-epidemic hyperendemicity) a raised endemicity of malaria within the areas covered by shading 7 is most foquently associated with irrigation, more especially with old, defective systems where leakage and water-logging are a feature. Such areas of raised endemicity are, however, usually limited in extent. Very rarely, even here, is the spleen rate comparable to that in the so-called hyperendemic tracts described later, and such high endemicity is seldom associated with the relative adult immunity so characteristically seen the true hyperendemic areas. To the north of the area of marked seasonal enhancement there exist, as indicated on the map, sub-montane areas where the endemicity may be permanently high, associated with hill streams etc.

Shading 3 indicates those extensive portions of India where, owing mainly to climatic and physical conditions (humid semi-tropical or tropical areas), malaria is much more stable in its manifestations. Here rainfall is both heavier and its excess less associated with enhanced incidence of malaria.

In innumerable towns, villages and hamlets, malaria occurs in varying degrees of intensity, practically never absent, and correspnodingly prevalent where local conditions are favourable.

Malaria here is largely a reflex of a multiplicity of natural features of the country, rain-water collections, streams and rivers, swamps, ponds and lakes (tanks). In addition, rice-fields and irrigation play their part. On the whole, throughout the area of shading 3, the endemicity is moderate to high, though areas of very low endemicity with a spleen rate under 10 per cent (healthy areas) are common. Some known healthy areas are indicated by shading 2; but insufficient is known at present as to the extent or permanence of such areas to make their mapping in detail possible. It is perhaps worth mentioning that some of the known healthy areas of this kind are not to any noticeable degree free from anophelines and that they may be and in fact usually are associated with extensive rice culture.

Within area 3, shadings 4, 5 and 6 indicate those tracts which it has been customary in India to refer to as hyper-endemic tracts. In the hyper-endemic tracts, the spleen rate is consistently and permanently high, rarely under 50 per cent, and frequently 90 per cent or over. Such areas of raised endemicity frequently have sharply definedd limits, so that passing beyond these, the spleen rate, often within a few miles, changes abruptly from the high values universal in the hyperendemic tract to low or moderate values characteristic of more healthy areas adjoining. In the more typical areas of this kind, the high spleen rate in children is associated with a relatively low rate in adults, and the adults also show considerable immunity to malaria and suffer little from its effects. Depending upon circumstances, however, there may be a high rate also in adults and in all cases non-immune immigrants show high malarial incidence. Non-immunes visiting such an area are extremely liable to contract malaria, often of a severe type, and Europeans and others of susceptible race resident in the area suffer constantly from malaria. Shading 4 represents known hyperendemic areas, where the hyperendemicity is associated with and appears to be an essential feature of low jungle of forest-clad hills (1000 to 3000 feet altitude) or terai country (foot-slopes of higher hills). This association of hilly country with enhanced malarial endemicity is one of the most marked and invariable features of malarial epidemiology in India, more especially in the south and east. Most of the notorious 'unhealthy' tracts are of this character and it is such areas which constitute the known endemic foci of blackwater fever, the only essential for such a focus within a hyper-endemic tract of this kind being the presence of resident Europeans or other susceptible race. As a rule such areas, though extensive, are wild and jungly in character, and populated by primitive aboriginal races who, beyong a universal infection in childhood, exhibit but little evidence of the disease. It is only where industrial enterprise (tea-planting, forestry, mining etc.) is attempted that the full potentialities of such areas are made fully apparent. Among better known areas of this kind may be mentioned the Sigur Ghat (referred to in Ross's earlier work), the Darjeeling Terai, and the Duars, the Nepal Terai, the Jeypore Hill Tracts, and the forsts of Singhbhum.

Shading 6 shows hyperendemic tracts not ofthis nature. Conspicuous among such is the extensive area of high endemicity studied by Fry, Bentley and others in the plains of Bengal. Here hyperendemicity is apparently associated with secular changes affecting the physical conditions (decayed rivers) and indirectly also through the diminished fertility of the soil and loss of trade etc., the economic prosperity of the population.

Smaller areas of local hyperendemicity seem in some localities to arise as a result of a slow enhancement of malaria through a period of years (epidemic malaria of tropical tracts); one such area formerly reputed healthy but later notoriously malarious is indicated on the map on the coast north of Madras City (Ennur etc.).

Lastly mention should be made of areas which by reason of altitude above sea-level are either entirely free from malaria or so relatively free that they show no definite endemic or epidemic prevalence. Roughly speaking, In India tracts or localities of 5000 feet altitude or over come within this category, but under special circumstances (Quetta) malaria may occur and even be prevalent at this height. These are shown by shading 1.

Hehir's regional synthesis accompanying the map

For our purpose here we may divide India into three main regions - Himalayan India, Middle India and the Deccan.

Himalayan India - generally over 1000 feet. It includes:

1. Himalaya East and Sikkim (East of Nepal)
2. Himalaya West and Kashmir (West of Nepal)

   At the foot-hills of both these areas there are elongated tracts of hyperendemic malaria
3 The North-West Frontier Province which contains the notoriously malarious valleys of the Indus and its tributaries and much irrigated land. The Indus and its branches are subject to serious flooding with inundations which are periodically associated with widespread epidemics of malaria
4 Baluchistan, a thinly populated arid mountainous district with generally speaking, mild malaria, but small patches of severe, endemic infection.

Middle India - The plains of Northern India, a widespread alluvial tract under 1000 feet above se-level, includes:

1 Sind, which forms the delta of the Indus, a rice-growing area, with, usually, moderately severe malaria but liable to periodical epidemic outbursts.
2 Rajputana West, with the Bikanir Desert, a thinly populated millet-growing country with moderate endemic malaria.
3 South-western Punjab, a semi-desert area with a scanty population and moderate endemic, but without epidemic malaria.
4 East and north Punjab a heavily populated wheat-growing area with, usually, moderately severe endemicity, but subject to overwhelming and appalling outbursts of epidemic malaria - it is the home of this latter form of the disease.
5 Western Division of the United Provinces, a heavily populated wheat and rice-growing area, normally with ordinary endemic, but liable to occasional epidemic malaria where it is co-terminous with the Punjab, and, so it would seem, an extension from the latter.

6 United Provinces East, a heavily populated rice-growing tract with typical endemic malaria, but with patches of hyperendemicity, where it runs into the foot-hills of the Himalayas; it is not subject to epidemic malaria.

7 Bihar, a country in which rice forms 60 per cent of the crops, with a population of moderate density. Is also a typical endemic malarial area.

8 Deltaic Bengal, densely populated by the Bengali race; rice forms 80 per cent of the crops; normally afflicted with ordinary endemic malaria, but is liable to hyperendemic outbursts. It is on the whole healthier than Upper Bengal.

9 Eastern Bengal, moderately heavily populated; 80 per cent of the crops consist of rice; it is subject to annual flooding over extensive tracts. Normally it is afflicted with endemic malaria, but like the Deltaic region, this in some years become hyperendemic or even epidemic.

10 Assam, the Brahmaputra valley, a densely populated rice-growing country that suffers from severe endemic malaria with patches of hyperendemicity

11 Gujarat, in the extreme west of the northern plains region, a thickly populated area with, usually, moderate endemic malaria, but subject to outbursts of hyperendemicity; epidemic malaria occasionally occurs.

<u>The Deccan-</u>

An extensive plateau of basalt and gneisses (especially granitoid), generally over 1000 feet high, here and there densely populated, growing mixed crops, with moderately sesevère endemic malaria, interspersed with patches, small and large of of severe malaria. It includes the Eastern Plain, Central Indian Plateau, East Satpuras (Plateau), Deccan (Plateau), South India, the Chota Nagpur Plateau, Jeypore Hill Tract, and the River Valley Plains, including Orissa.

1 Easterm plain.- Under 1000 feet high. It includes the moderately well-populated rice-growing districts of the Carnatic Plain, Tanjore, Coimbatore etc., with mild endemic malaria; much of it is unsurveyed. Also the Madras Hills (Nilgigis, Palnis etc.) with moderately severe malaria at the foot of the hills. Likewise Madras Coast North, part of the area south of the Godavari, and the Godavari, Kistna and Nellore districts, all rice-growing areas with a moderately full population, and with, generally, ordinary endemic malaria. Madras Coast North, however, includes the Jeypore Hill Tract, a rice-growing district with severe endemic, and in some years even hyperendemic malaria.

2 River-valley Plains, including Orissa. Well-populated areas, containing much flat rice-growing land in the valley of the Mahanadi, with moderately severe endemic malaria.

3 Central Indian Plateau, which includes Eastern Rajputana and Central India West, which have mild malaria

4 East Satpuras (Plateau) which embraces Central India East and Central Provinces West, a thinly populated wheat-growing area, with mild endemic malaria except at the foothills where it is severe.

5 The Deccan Plateau proper, which embraces the Hyderabad

State, with the upper part of the Godavari, and the Bombay Deccan, mostly with mild malaria, interspersed with really healthy districts.

6 South India, which includes the Madras Deccan (Cuddapah, Kurnool, etc.) - rice-growing areas, well-populated, with mild endemic malaria - and Mysore, which is healthy.

7 Chota Nagpur Plateau, thinly peopled by aboriginal races, rice-growing, with mild endemic malaria.

8 River Valley Plains of the East Central Provinces; contains the valleys of the Goadavari and Mahanadi; well-populated; much irrigated land under cultivation; ordinary endemic malaria with patches of greater severity.

9 On the West coast we have Konkan in the Bombay Presidency, and Malabar in the Madras Presidency, both with heavy rainfalls, ordinary endemic malaria, with extensive areas of high endemicity, sometimes hyperendemicity.

APPENDIX B.

Cholera - A review of some of the medical literature from a geographer's point of view.

Cholera is an intestinal disease caused by the bacillus called vibrio cholerae or vibrio comma of Koch. It is an acute disease, with a case mortality in India often of the order of 50 per cent, although this may be decreasing. The infection is from the faeces or vomit of a patient or recent patient (the 'healthy carrier' of cholera does not seem to have been proved to exist, see p. 159). And it may take place directly through personal contact, or through contamination of water or food, including the conveyance of the organisms by flies.

The geographical relations of cholera have been described in general terms by May (1951):-

"Epidemic outbreaks have occurred in different climates, though some parts of the world have remained completely unaffected." Or cholera may remain "quiescent, showing its presence by continuous small numbers of cases, which at certain times and during certain seasons become epidemics of various morbidities and mortalities. This type of cholera is confined to certain districts of India. For these reasons we distinguish the study of occasional or epidemic cholera from that of endemic or permanent cholera. Occasional cholera is closely linked to factors of human geography. It correlates with the density of population, permanent or transient. When large numbers of susceptibles are gathered together, as on pilgrimages, those coming from cholera-infested areas bring the disease with them, spreading it everywhere on the way. They contaminate their fellow worshippers, who in turn spread the pestilence as they return to their homeland.

As one has to eat or drink the germ of the disease to become contaminated, the cultural habits and ritual of human groups, their social customs and amenities, influence to a great extent its areal distribution and morbidity.

"The disease is also linked to factors of economic geography, spreading through the inhabited world along the routes of commerce, by caravans, ship lines, or railroads, at a speed that is sometimes, but not always, proportionate to that of the carrier. (Compare the slow advance by caravan of the first three pandemics, with the rapid advance by steamship and rail of the fourth).

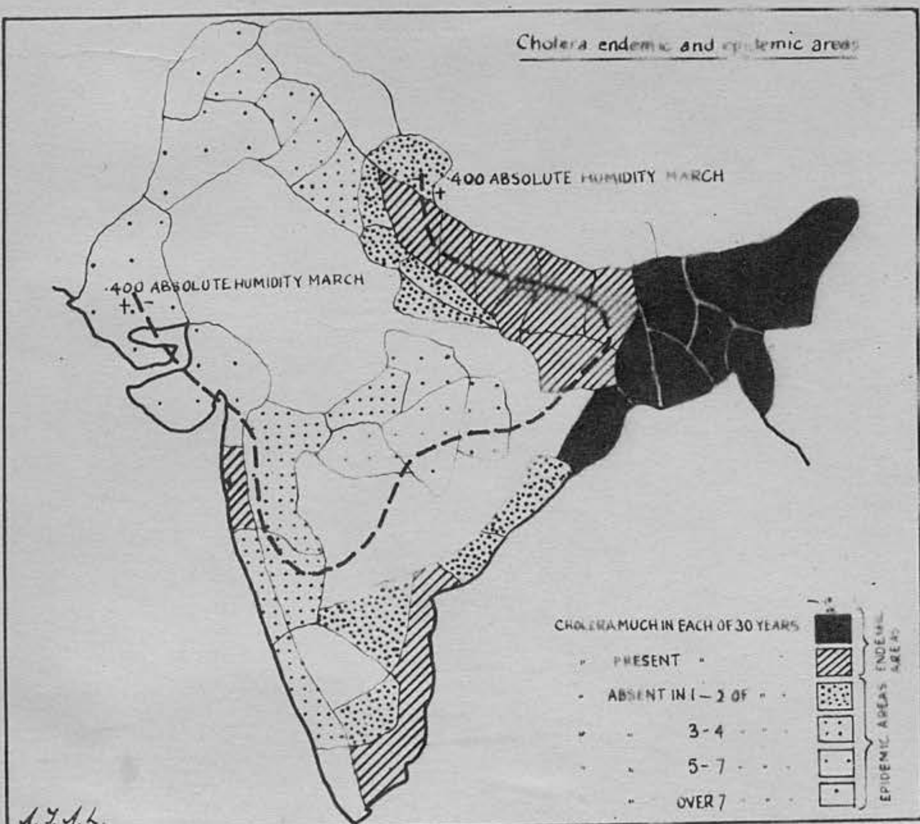
"The disease is also linked to factors of physical geography. Epidemics break out in hot, humid weather and frequently die out in winter. In some places (wet tracts like Bengal) an epidemic ends with the onset of the rainy season; in others (of lesser water supply) the rains help to spread the polution of water bodies. On the east coast of Africa up to the end of the last century, cholera, when it occurred, coincided with the arrival of the north-east monsoon, which brought dhows from India.

"Permanent cholera seems to be found well below the 500-meter line in India, where the population is dense, and temperatur and humidity are always high. In these places the germ remains quiescent either in man or nature during certain seasons if it can find sheltered bodies of water rich in organic content and salts.

We have tried to show these various features on several maps."
(Most of these maps are reproduced in the course of the following discussion).

India has often been referred to as the 'endemic home' of Asiatic cholera; certainly Bengal is an endemic centre of great extent and importance, and, as will be shown, there are others, in other deltas of the eastern seaboard of peninsular India, around Bombay City, and in the lower Ganges basin, especially along the hill-foot. In these endemic foci the disease periodically flares up in epidemic form, and then it may spread to any part of the sub-continent, in more or less violent epidemics, often with a tendency to recur at intervals of about six years.

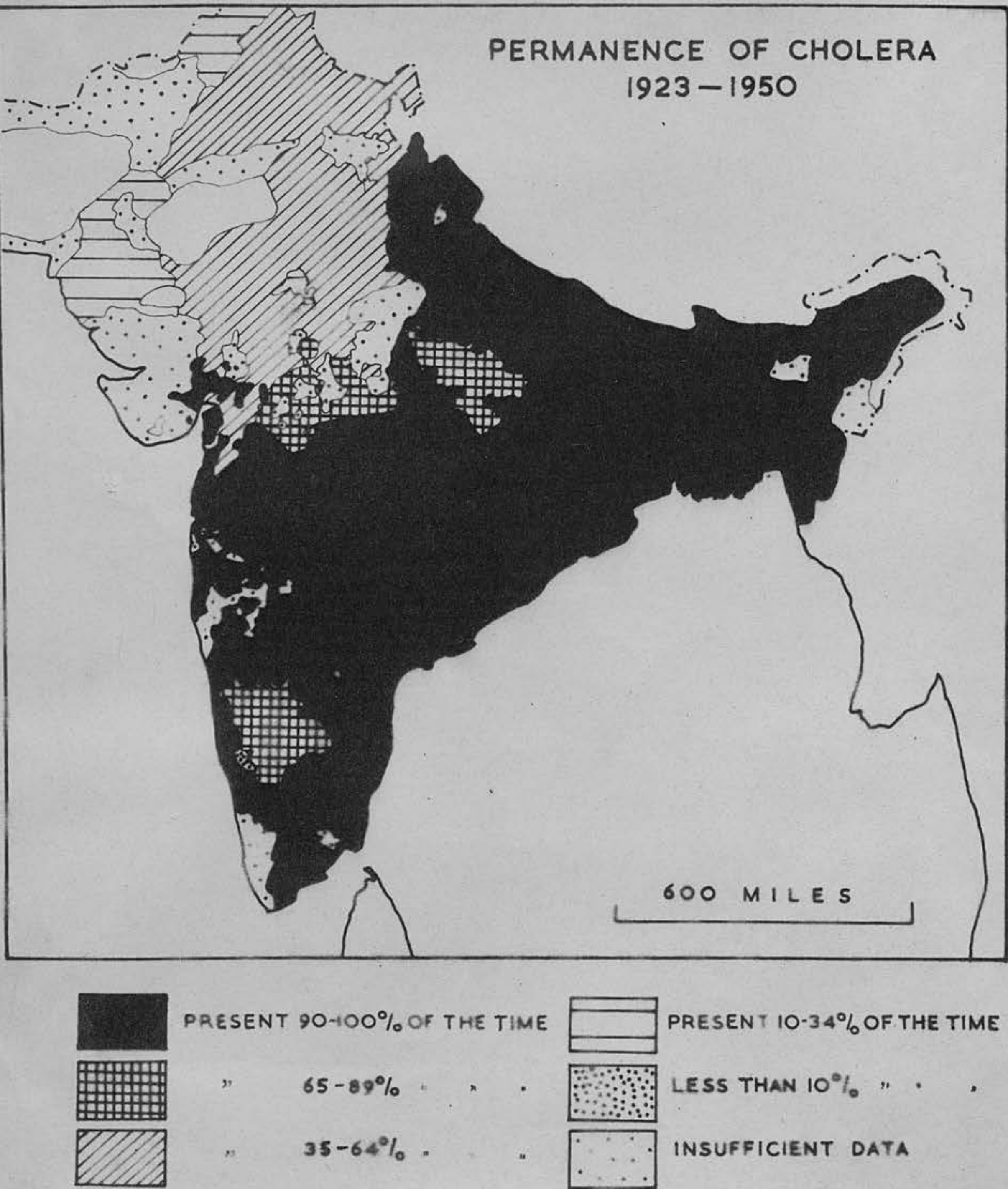
The mortality from cholera has been analysed for the period 1877 to 1922, by Rogers (1928) who correlated it by simple graphic and cartographic methods with data from the Meteorological Atlas of India of 1906, as well as with certain human factors such as pilgrimages. His most important conclusions concern the extent of and relations between the endemic and the epidemic areas of India, throwing light on the differing seasonal incidence; and his belief that of the existing climatic data, the most significant for cholera potentialities under existing conditions in India is the number of months with an absolute humidity of over .4 inches (of aqueous pressure as measured by a mercury column at 32° F.). His aim was to forecast severe incidence of cholera; subsequent years proved his methods to be only fairly successful. In reading the papers concerned with climate and cholera one is struck by the paucity of data concerning ground water. Thus the apparent re-


Cholera endemic and epidemic areas
400 ABSOLUTE HUMIDITY MARCH
400 ABSOLUTE HUMIDITY MARCH
CHOLERA MUCH IN EACH OF 30 YEARS
PRESENT
ABSENT IN 1 – 2 OF
3 - 4
5 - 7
OVER 7
ENDEMIC AREAS
EPIDEMIC AREAS
A.T.A.L.

lation with absolute humidity may in fact be a relation with a high water-table.

Rogers' map shows more and larger endemic areas than earlier writers had indicated even including his own previous work (fig. 40). Within the endemic areas, cholera had been conceived as travelling outward from <u>the</u> 'endemic home' in Bengal, (as the older, narrower view had regarded it). This was the view with which Rogers began but he came to see it rather as springing up from quite numerous and widely scattered, often small, perennial endemic foci within the several areas demarcated on the map. Rogers believes that this change occurs when conditions favourable to the vibrio maintain for a sufficient length of time for an epidemic to gather force - perhaps a month or more. Thence the infection does actually travel into the true epidemic areas. Often a direct human chain of infection can be traced, through pilgrimages, cattle fairs, marriage parties etc.; but the outbreaks consequent on these movements of people and infection will give rise only to small and local outbreaks unless factors favouring the vibrio be present.

It may be that only those areas of Assam adjacent to Bengal (and I think, sharing the deltaic environment) are true endemic areas, although some areas do have epidemic cholera every year (see also p. 159 on movements of population) (Rice 1935). Russell and Sundararajan (1928) suggest that it may be especially East Bengal and Assam that are true endemic areas; they certainly establish differences between East and West Bengal which are summarised below. It is also argued that Rogers' classification of the hill-foot Districts of the U.P. as an endemic region,


PERMANENCE OF CHOLERA
1923 — 1950
600 MILES
PRESENT 90-100% OF THE TIME
" 65-89% " "
" 35-64% " "
PRESENT 10-34% OF THE TIME
LESS THAN 10% " "
INSUFFICIENT DATA

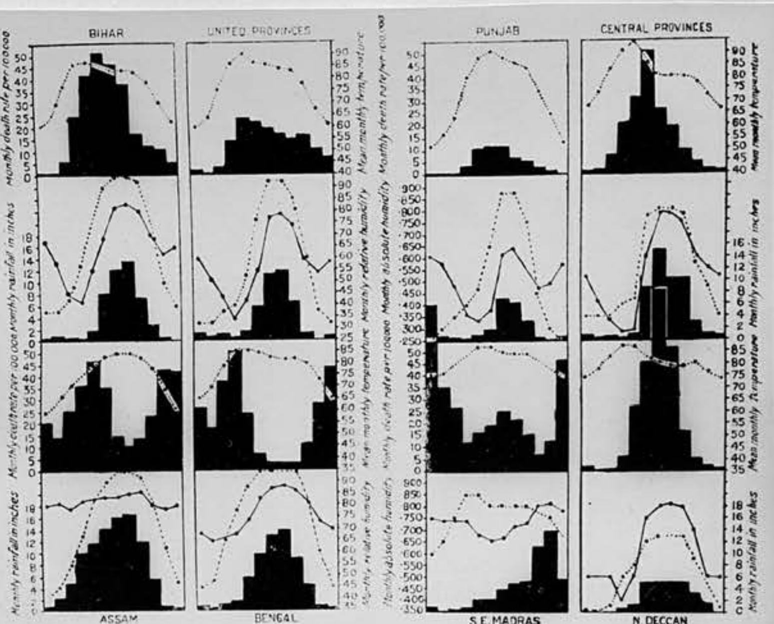


CHART I.—Cholera and climate in India.

42.

based on mortality figures, is in error, in that the infection is due to invasion from the Nepal terai, for which latter area no mortality figures are published: the hill-foot region, however, seems still to be incriminated (Saranjam Khan 1929-30).

A map of "permanence of cholera 1923-1950" has been adapted as figure 41 , (May 1951). This may be compared with Rogers' map of endemic and epidemic areas, and with the present writer's map combining a grouping according to intensity of incidence with one according to degree of variability (fig. 26A).

The graphs of cholera mortality and certain climatic elements have been reproduced from Rogers' paper as figure 42 . The mortality generally rises with the monsoon rainfall, although south-eastern Madras naturally has a very different pattern since it receives most of its rain from the retreating monsoon (the 'North-East Monsoon' of older writers). Bengal and Assam, however, show a fall of cholera mortality at the time of the monsoon, and have in fact two minima, one then and one in February, with maxima in the autumn and in April. It has now been shown that only East Bengal and Assam have in fact this different pattern of seasonal incidence, and that the mortality in West Bengal rises with the onset of the monsoon, and flushing of polluted ground by first downpours and downwash (Russell & Sundararajan 1928).

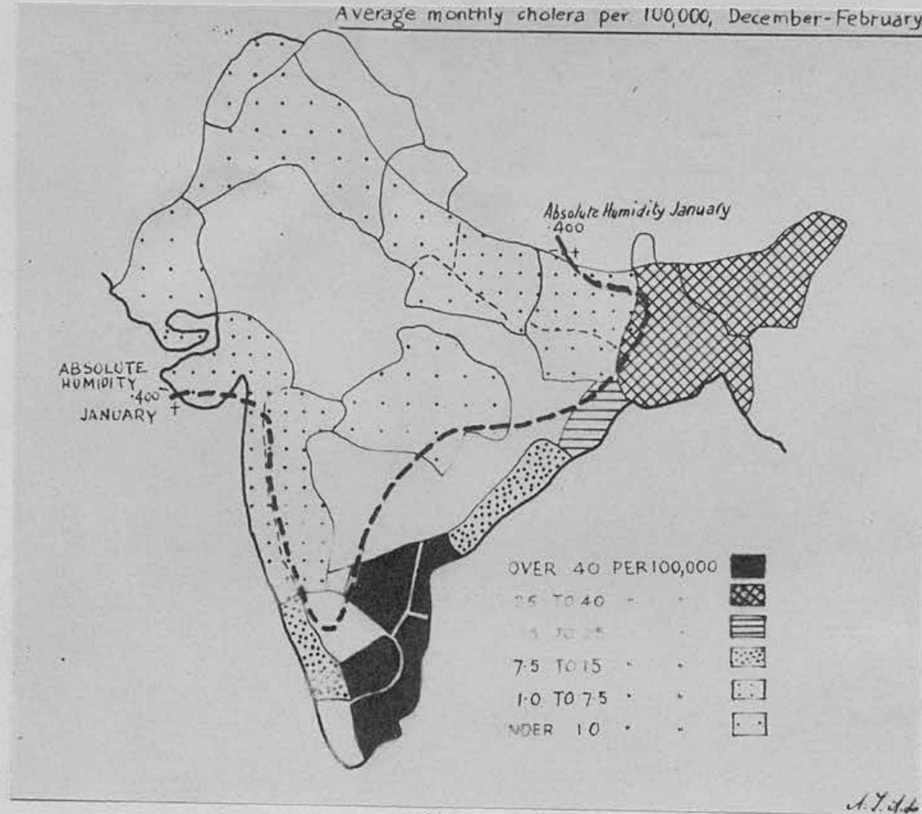
Rogers points out that correlation with relative humidity also presents difficulties: in the Punjab, for instance, relative humidity is almost as high in the cool weather when cholera is low, as in the monsoon when most of the deaths occur. Absolute humidity below .4 inches seems to inhibit the activity of the cholera in some way; even if other circumstances are favourable, for instance an outbreak at a great religious fair, no great epidemic results if the humidity is below that figure. Humidity above that figure, on the other hand, permits cholera to flourish if other circumstances are suitable.[1]

A failure of the monsoon in the previous cultivation season favours the rise of cholera, through the progressive worsening in quality of water supplies (and possibly also through the association with poor nutrition ATAL). Exceptional floods also favour cholera, acting through privation and lowered resistance (rather than through polluted water supplies at least during the actual floods when the dilution factor is important ATAL). In East Bengal and Assam, where the humidity is favourable to the vibrio all year, the fluctuations are due to complex causes. The low mortality rates during the monsoon, the time of sheet floods, are due to the flushing of the whole area by fresh flood-waters, and the rise comes as they retreat, when more stagnant and polluted sources of drinking water come to be used.

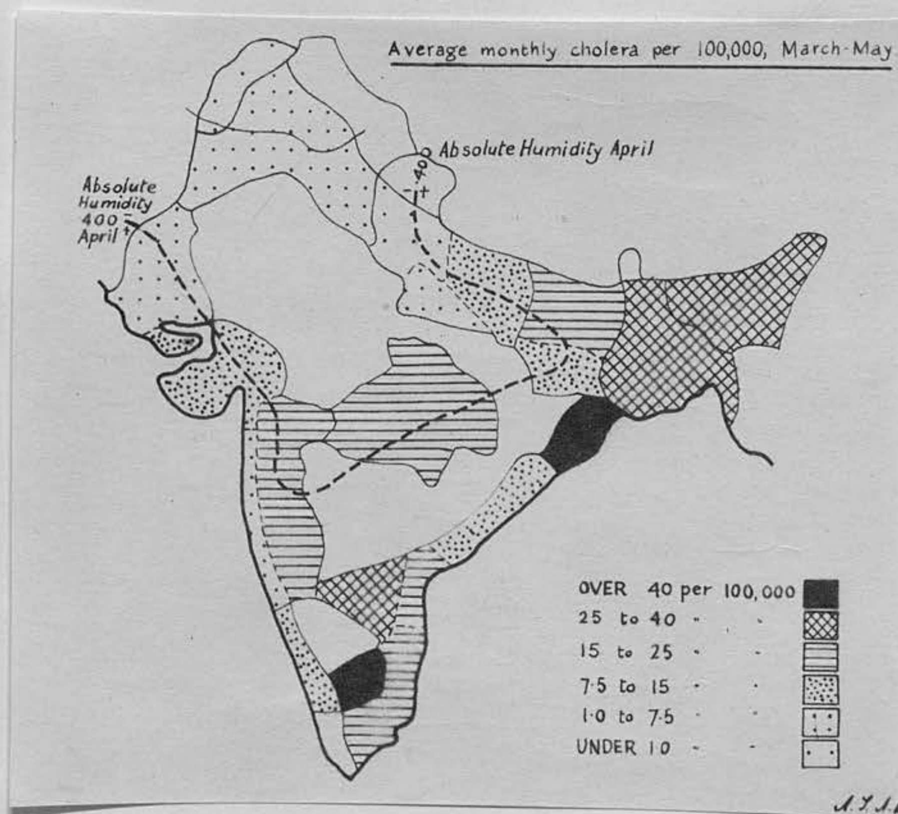
The march of the seasons in respect of average cholera mortality and Rogers' crucial figure of absolute humidity may be followed in his own maps, adapted as figures 43 to 46.

In figure 43 , the areas severely affected by cholera lie in the relatively small area of the sub-continent to the

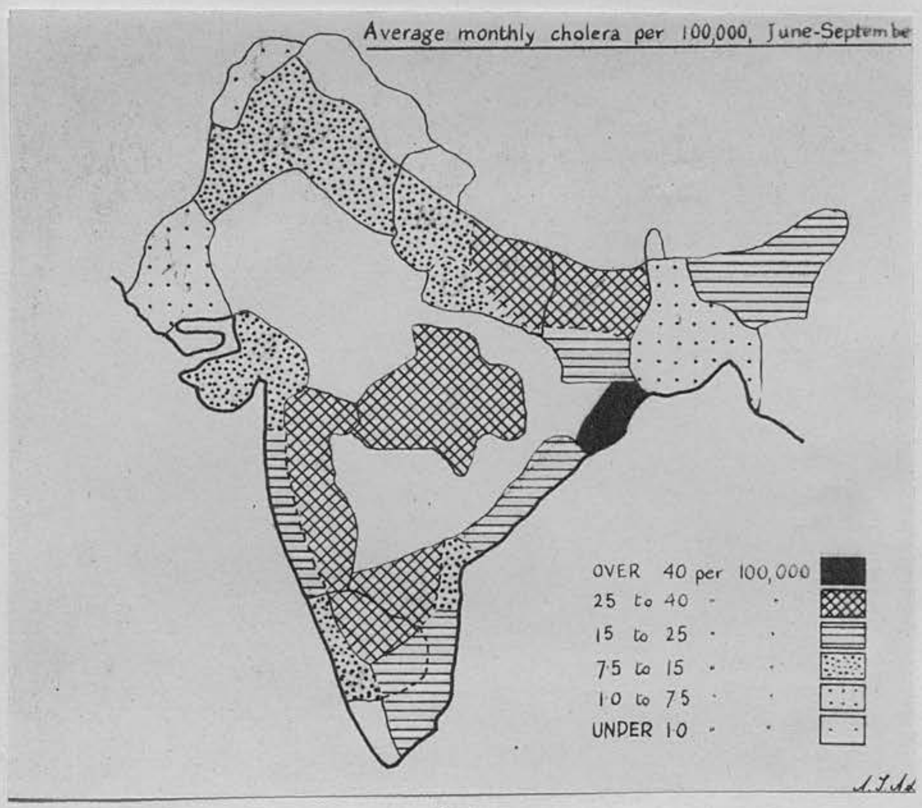
1. Rogers' work in this respect has been supported by findings from the Shanghai area (Wei, 1949).


Average monthly cholera per 100,000, December-February.
Absolute Humidity January
·400
ABSOLUTE HUMIDITY ·400
JANUARY
OVER 40 PER 100,000
25 TO 40
7·5 TO 15
1·0 TO 7·5
NDER 1·0
A.T.A.L.

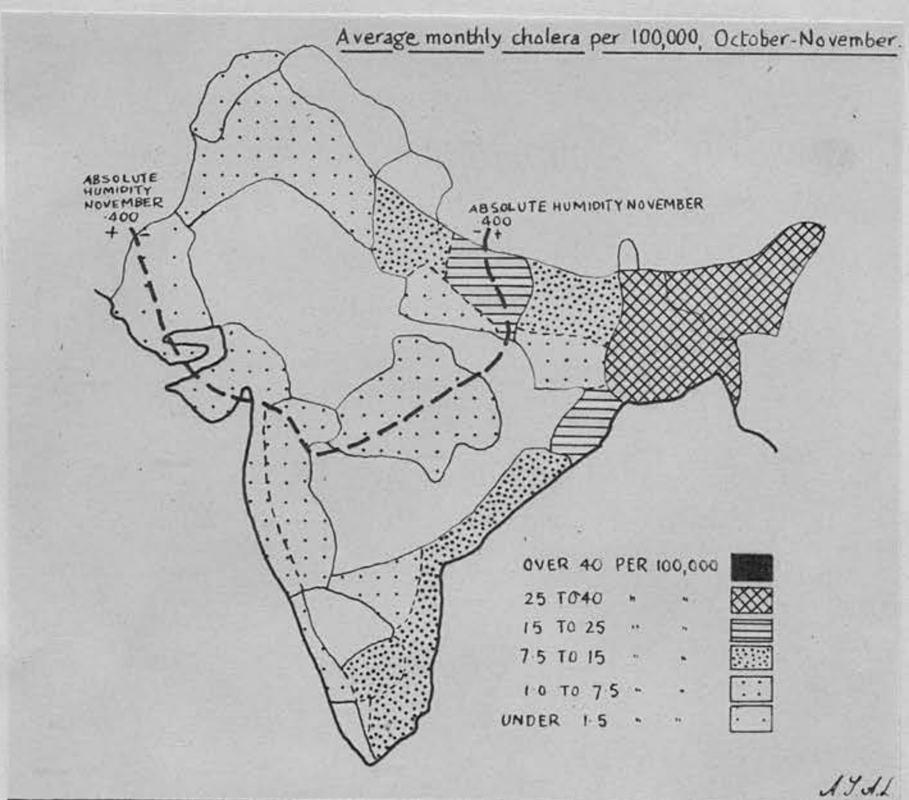
43


Average monthly cholera per 100,000, March-May.
Absolute Humidity April
·40
Absolute Humidity ·400 April
OVER 40 per 100,000
25 to 40
15 to 25
7·5 to 15
1·0 to 7·5
UNDER 1·0
A.T.A.L.

44


Average monthly cholera per 100,000, June-Septembe
OVER 40 per 100,000
25 to 40
15 to 25
7.5 to 15
1.0 to 7.5
UNDER 1.0
A.T.A.L.

45


Average monthly cholera per 100,000, October-November.
ABSOLUTE HUMIDITY NOVEMBER .400
ABSOLUTE HUMIDITY NOVEMBER .400
OVER 40 PER 100,000
25 TO 40
15 TO 25
7.5 TO 15
1.0 TO 7.5
UNDER 1.5
A.T.A.L.

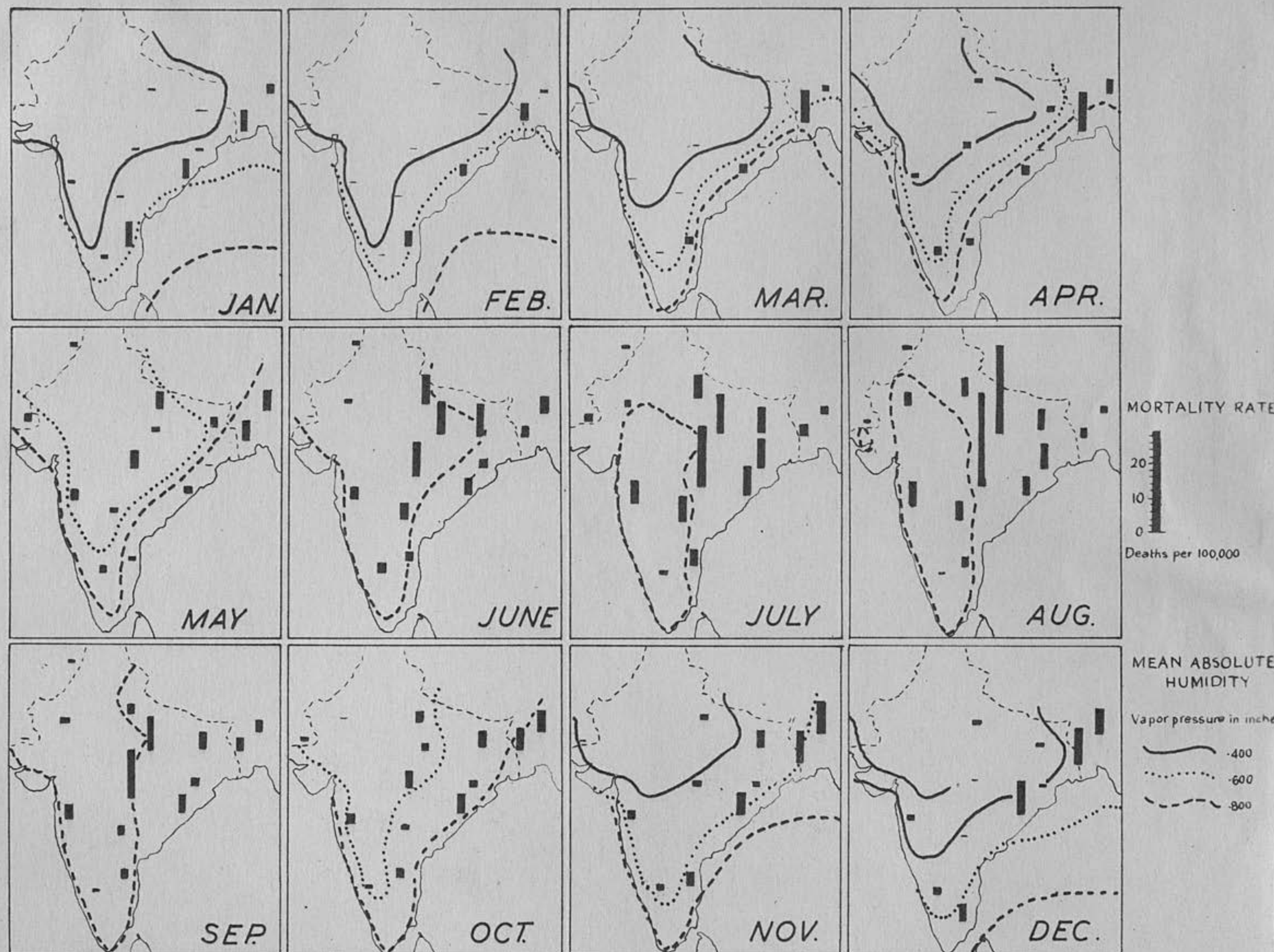
46

south and east of the chosen isopleth for an absolute humidity of .4 inches. In figure 44) the isopleth has retreated to the north-west, while the area of moderate incidence of cholera has advanced upon it. In figure 45 ') none of India has less than the crucial figure of .4 inches and this is the season when epidemics do travel from all the endemic areas into the epidemic areas, which, however, nevertheless appear relatively light in a map of this kind. The epidemic area in the heart of the peninsula is severely affected, as is also the endemic area of United Provinces. The Bengal delta shows as low, for the reasons explained, but the neighbouring Orissa delta has very high mortality (see p. 156). In figure 46 , the isopleth has appeared again, half-way to its cool-weather position; and cholera is generally on the ebb, but Bengal and Assam are now severely involved. Eastern United Provinces and the Orissa delta are still fairly high. May (1951) has followed the relations of cholera mortality for a shorter period (ten years), with the .4 inches and other isopleths of humidity, but mapped month by month; Rogers' work receives considerable support from these (Fig. 47).

Russell and Sundararajan (1928) have used statistical techniques in searching for correlations between cholera mortality and climatic factors, in a massive attempt to give precision to more subjective views of these relationships which many workers h felt to be important. They used monthly cholera mortality for thirteen groups of Districts or cholera areas, which they considere to be more or less homogeneous from this point of view; but occasional violent fluctuations, which might be held to be due

MONTHLY OCCURRENCE OF CHOLERA IN INDIA

AVERAGE FOR TEN YEARS



47

fortuitous factors, were eliminated by the device of the 'moving average', on a twelve monthly basis (i.e. the figure plotted for June was in fact the average for the twelve months January to December, that plotted for July is the average for the twelve months from February to the following January, and so on). This was related to a figure for (a) rainfall, (b) relative humidity (c) temperature, and (d) pressure, firstly for the actual month concerned (termed lag_0), and then, in case of delayed effects from a climatic change, for the two following months (termed lag_1 and lag_2 respectively). These climatic figures were obtained by averaging all the available data in the 'cholera area' concerned.

The results may be summarised as follows:-

Rainfall The coefficients of correlation were positive and significant for lag_0 and lag_1 for nearly all areas - that is there is a high degree of correlation between rainfall and cholera mortality. In south-eastern Madras, lag_2 is positive and significant; it has long been known that there is a delay of some six to eight weeks after the main rains before cholera becomes severe. The reasons for this contrast seem to spring from a complex of factors. It is suggested that in the drier areas especially, the onset of the monsoon washes accumulated filth by sheet-wash from the dried and sun-cracked earth (notably the black cotton soils). One must add, however, that under these conditions only very recently deposited faecal matter would be capable of transmitting cholera owing to the powerful bactericidal action of the sun. On the other hand the six to eight weeks' delay in the more fertile and densely peopled areas of the peninsula is thought to be linked with the rise in the water-table, which comes after a similar delay.

In East Bengal the correlations are in complete contrast, for they are negative and significant (see also p.141). In the findings in Assam are negative but not significant compared with the possible errors.

<u>Relative Humidity</u> Correlations are nearly all positive, significant, and without lag. South-eastern Madras shows more direct correlation with humidity, with less lag, than in the case of rainfall. It is suggested that the correlation of high cholera and high relative humidity may be connected with the rise in the water table mentioned above, since the high water-table and high humidity approximately coincide. In Bengal the correlations are all negative and significant for lag_0 and lag_1. In central and eastern Bengal the expected correlation between humidity and rainfall is obtained for the first time. Assam shows significant negative correlation at lag_1.

<u>Temperature</u> There is generally a high degree of correlation especially at lag_1. The authors suggest that this may be due to a delay of some weeks before the change in temperature can take effect. One might add that the system of recording climatic data by calendar months results in high rainfall appearing in the month after the highest temperatures are shown, for very many Indian stations. In this case the Bengal coefficients are positive and highly significant. The Assam data again show no significant valu-

The authors are at a loss to account for the consistent lack of significant correlations from Assam; it appears as if climatic conditions are so favourable to the disease throughout the year that other, probably human factors take precedence; one might suggest also that areas dissimilar from the point of view of the epidemiology of cholera have been dealt with together, and that this has invalidated the results in fashion comparable with the difficulties encountered by the authors in the case of Bengal before they discovered the differences between East and West Bengal. The area of south-eastern Madras, deriving most of its rainfall from the retreating monsoon in the cool season and having most of its cholera thereafter, is, of course, exceptional in having a negative correlation with temperature. Just as the cool season temperatures of over 70° F. (monthly means) do not inhibit the growth of tropical crops, so too the 8 am temperatures are above the figure of 60° F. which tends to curb the activities of the vibrio. (In this connection Saranjam Khan (1929-30) observes that with a temperature of under 60° F. for two months, cholera vanishes or becomes very low, and an endemic focus is unlikely.)

Pressure The results are naturally generally inverse with those for rainfall; they need not be discussed further here.

So far the discussion has been mainly concerned with two long papers by Rogers and by Russell and Sundararajan. Rogers' simpler methods have the advantage that the author was able to point to a crucial figure of absolute humidity, to be interpreted along with other physical and human factors of course; this has proved of some value although forecasting has so far proved more difficult than Rogers hoped. The work of Russell and Sundararajan, from the point of view of this essay, gives a valuable statistical basis for a regional view of cholera. On the whole the two works are consistent and complementary, yet Rogers rejected relative humidity whereas Russell and Sundararajan use it as the basis of that part of their analysis. This conflict is more apparent than real, since cool-season conditions in the Punjab, which primarily caused Rogers' to avoid further investigation of relative humidities, are exceptional in the sub-continent, as are the associated rain-bearing depressions of those months. And they occur at a season when minimum daily temperatures frequently fall below the crucial temperature of 60° F.

<u>The problem of recrudescence in epidemic areas</u>

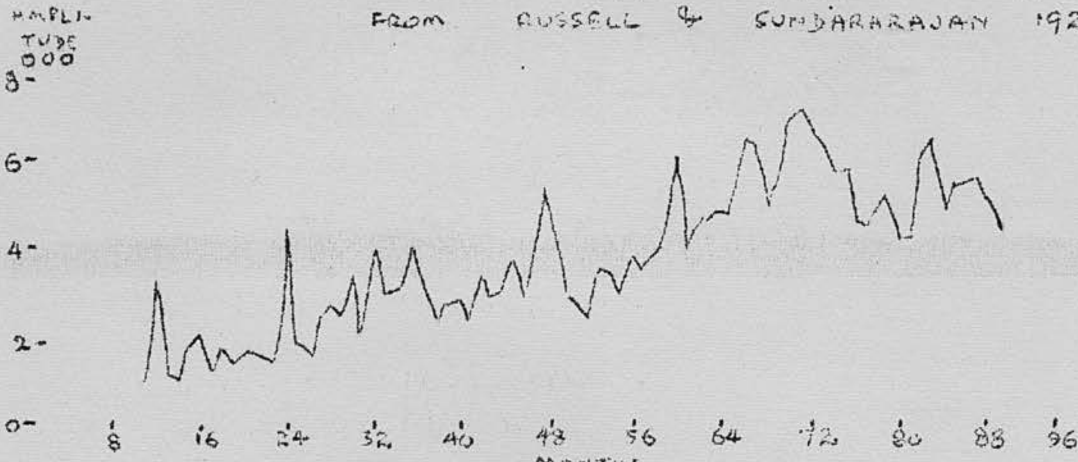
Cholera normally dies out in the cool season in the true epidemic areas, but occasional recrudescence in the spring has been reported especially from Punjab (Rogers 1928). Gill and Lal (1930-31) quote a most interesting instance in Kashmir in 1925, when a few cases occurred throughout the winter, although the temperature was below freezing point and snow was on the ground. In the spring came recrudescence, and massive infection of the Jhelum which has a considerable semi-aquatic population of boatmen; the infection was spread far and wide, because of a religious fair whose rites included the drinking of water from the Jhelum. Ten thousand deaths resulted.

<u>The indirect effects of climate</u>

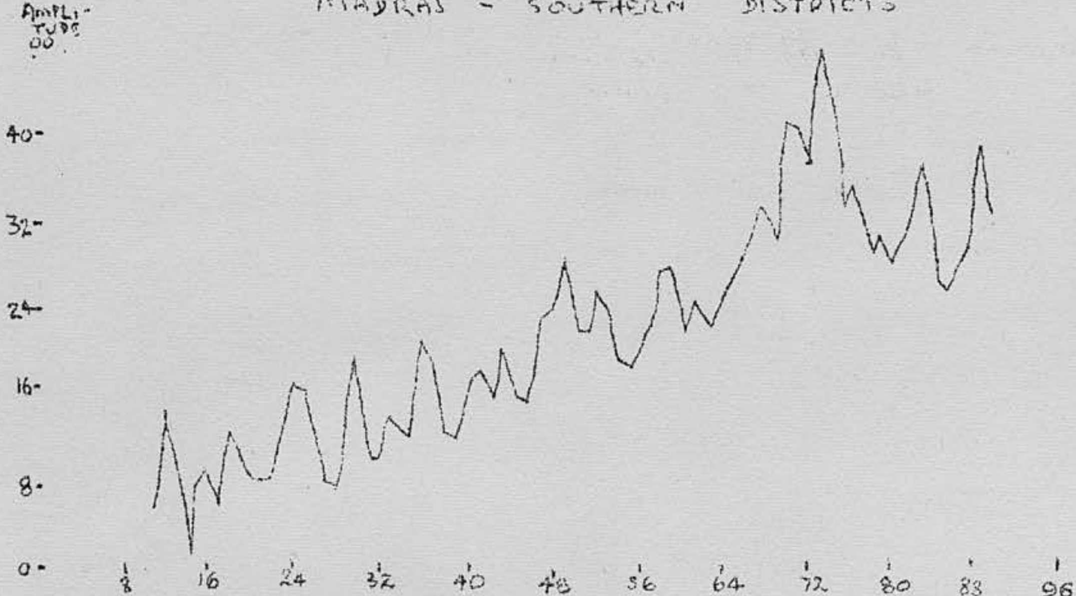
It has been forcefully argued that the true significance of th climatic relations of cholera, especially the association with humid heat, is to be found in the bionomics of the house-fly (Ross 1928). Other workers have contributed and some account of their findings is given on page 152.

FIGURE 48.

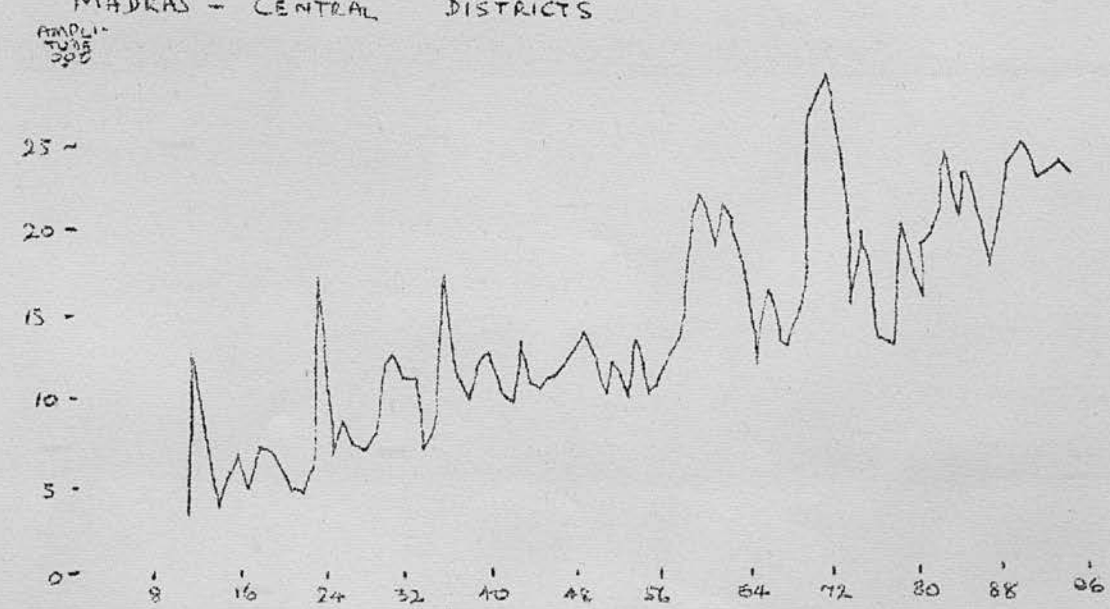
'PERIODOGRAMS' FOR CHOLERA – SELECTED FROM RUSSELL & SUNDARARAJAN 1928.

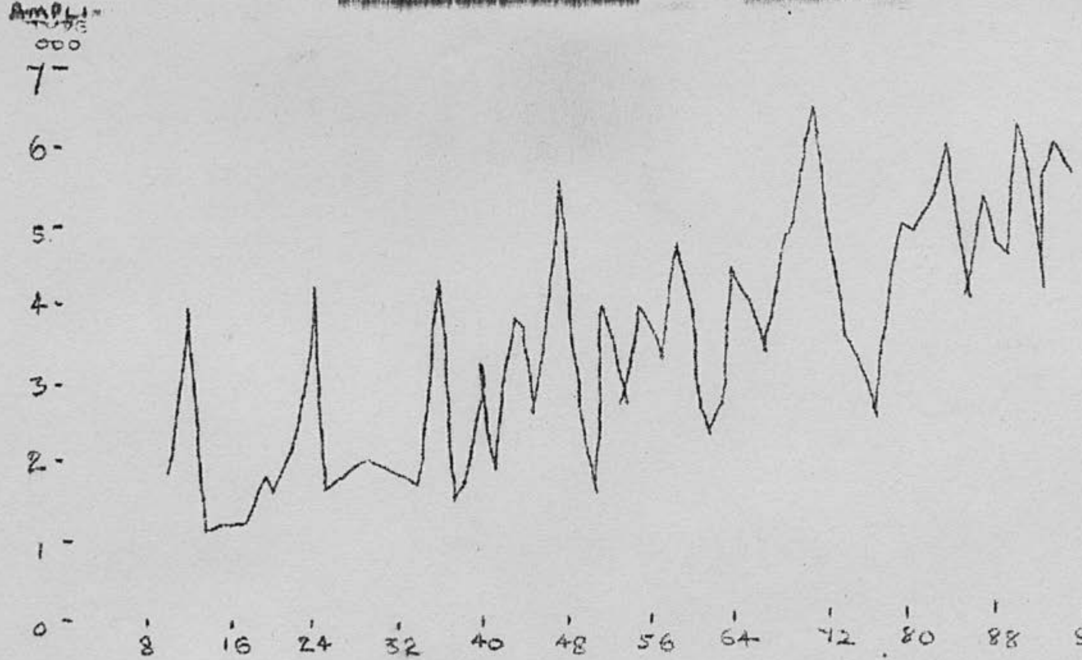


MADRAS – SOUTHERN DISTRICTS

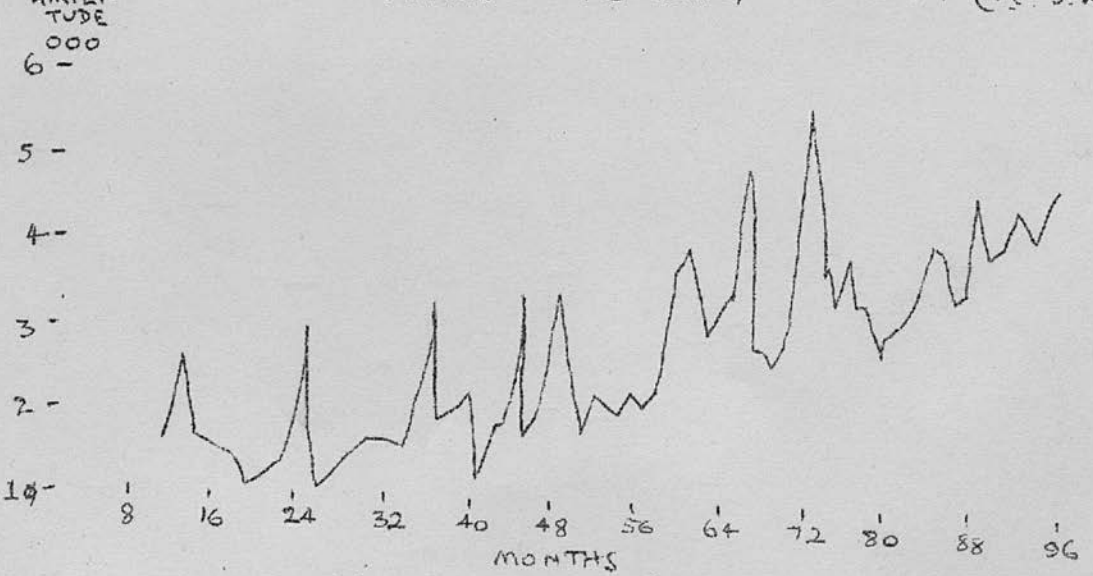


MADRAS – CENTRAL DISTRICTS





BENGAL - PRESIDENCY DIVISION (I.E. S.W. BENGAL)



BENGAL - DACCA & CHITTAGONG DIVISION (I.E. EAST BENGA

The cyclic tendency of cholera over a term of years

Rogers (1928) was unable to find any regular cycle of 'cholera years', beyond the sequence of years of relative quiescence which often follow after a severe epidemic, owing presumably to the relative scarcity of 'susceptibles' for the time being; earlier workers had suggested that there is a three-year cycle.

On the other hand, the more refined statistical methods of Russell and Sundararajan (1928) gave more positive results in this instance, and proved that a six-year cycle predominates in most of India.

The test for a cyclic tendency was carried out by means of 'Brownlee's periodogram', evolved originally in studying measles in Britain. The monthly incidence is considered in relation to a graph in which the units of the abscissa line represent periods of .....8,9,10,11,12,13......60...72..84..96 months. The units of the ordinates line represent amplitudes of the cholera wave recurrent at those intervals. The graphs are reproduced as figure ~~s~~ ~~40~~ 48.

They show that almost all India has a marked maximum at 72 months, and that East Bengal and Assam are exceptions in having their maximum periodicity consistently at about 60 months. This exception may be of significance in relation to that great area of endemicity. The United Provinces have a peak at 72 months, but have a double maximum at 83 and 63 months; but it is considered that this may be due to comparatively few exceptionally large figures distorting the graph.

Hydrography and water-supplies

Since it was confirmed at Hamburg-Altona in 1892 that cholera is a water-borne disease, much attention has been paid to improving water-supplies in affected areas. This has been done in somewhat patchy fashion in many parts of India, but the cholera figures often do not show the improvement that might have been expected. This will be discussed further in considering explosive and protracted outbreaks (p. 152).

The medical literature contains a certain amount of information about the qualities of various natural waters of India, from the point of view of cholera.

It has long been known or suspected that certain natural waters are unfavourable to the vibrio. As long ago as 1911, Rogers, in his classic book on cholera, suggested that the waters of the Jumna at Agra are inimical to it. Some further work has followed (Saranjam Khan etc. 1928-29, Saranjam Khan 1930). The vibrio dies quickly when added to water - within 24 hours in the case of Ganges and Jumna waters, compared with three days if it is placed in boiled water. Experimental work suggested that this is because of loss of competition, and indeed the dead bodies of what would otherwise have been competing organisms, in the boiled water, may provide food for the vibrio. In filtered water, on the other hand, the vibrio dies more quickly, because of lack of food.

Tentative findings have been offered on the conditions for growth and survival of the vibrio on water (Read etc. 1939-40). Some degree of salinity and a certain amount of organic matter are needed for multiplication and survival, the need for salt decreasing as the amount or organic matter increases. The presence of other organisms is not inimical to the cholera vibrio, except for the very similar but harmless (inagglutinable) vibrios, but even in the presence of these latter, the cholera organism can survive for three weeks. (This is much longer than Saranjam Khan's work would indicate but laboratory findings pure and simple often conflict with results from investigations of somewhat more natural conditions). In the Calcutta area, these needs are met in most open waters, and there is some correspondence between cholera incidence and 'total solids' in water analyses. The November rise in cholera, it is tentatively suggested, may be linked with some change in conditions in the waters. Again for the greatest single endemic home of cholera in the Bengal delta, some further data are given by Govinda (1931). Surface waters naturally vary greatly in space and time, in respect of both salinity and organic content. After the monsoon bursts, hardness is reduced to about a quarter of the May figure (presumably salinity is also reduced, and the figure applies to a water-channel affected by flood-waters). Even tube-wells have a general increase in salinity towards the seaward edge of the delta. Thus in Hooghly, salinity is of the order of 60 to 150 in 100,000 parts, whereas at Shamnagar 20 miles upstream, it is about 1 in 100,000. This salinity of deep waters is not caused directly by contact with sea water, but through impregnation of the soil. There are anomolies. Thus an analysis at Chittagong on the extreme east of the delta gave the lowest recorded salinity figure, because of the influence of the very heavy rainfall on the mountains farther east whereas Rajshahi in the north of the delta gave a rather high figure apparently because the soil is still impregnated to some extent with salt as a legacy of the times when the water-channels in the area were still tidal. A slight seasonal variation is found, inverse with the changes in surface waters: thus when salinity and hardness are reduced in surface waters by the monsoon, and monsoon floods, the tube-well figures are increased slightly, because the generally increased flow and higher levels of sub-soil waters brings in additional salinity. The original paper gives details of organisms found in tube-well waters, and a theory concerning their origin, but it should be said that despite this discovery, and these changes in salinity, the tube-well water has not been incriminated as a source of cholera.

In the endemic areas of cholera, the recorded rates of infection of natural waters by vibrio cholerae in small or great numbers, are very high. In Calcutta, tube-wells and piped drinking water were free from the vibrios, but they were present in domestic water-cisterns, and in all specimens examined from rivers and tanks (in the Indian sense of large ponds). (Pasricha etc. 1938). In Assam, 90 per cent of all open-water sources were infected, including tanks and ponds, wells, and streams (Pandit etc. 1938). In Punjab, on the other hand, investigations of water from similar sources in areas chosen because cholera had not occurred recently showed only the harmless (inagglutinating) vibrios which seemed to have no relations with cholera and for which a 'water origin' is suggested. (Taylor etc. 1938).

Among modern case-histories of communities attacked by water-borne cholera were certain outbreaks in Assam, which show its dominance (Morison (1934)). Interactions with human factors are important, like the concealment of the disease among a group of seasonal immigrants from Bihar when fishing a backwater of the Brahmaputra - concealment lest the sales of their fish be affected; or again the local medico-religious custom of gathering all the men of about the same age as the patient to have a meal. On the other hand there have been offered some cogent arguments against concentrating too much attention on water-supplies, usually by workers presenting the case against the house-fly (see p.152). Thus Ross (1928) points to the fact that cholera spreads up the Ganges, not downstream - a fact which partly accounted for the earlier wind-borne theory. Gill and Lal (1930-31) suggest that water is commonly associated with an explosive outbreak, in contrast to the more protracted type of outbreak where flies are more probably involved. The explosive type of outbreak accounts for one some 2.5 per cent of all outbreaks in Punjab (although doubtless for a higher proportion of deaths from cholera). The supply of piped water to many communities has not eliminated cholera. Again a few scattered cases continued to occur daily during a well-studied outbreak in Kasur Town, which incidence was not suggestive of the contamination of a few of the town's 786 wells, especially as these were in any case disinfected. Nicholls (1934-35), in investigating cholera among temporary immigrants to Ceylon, found a similar contrast between explosive outbreaks clearly linked with contamination of water supplies, and a more protracted type of outbreak in which, however, he was able to trace the links in a chain of infection, from patient to patient.

A change in the virulence of the vibrio cholerae is also a possible cause of the contrast between explosive and protracted outbreaks. One line of investigation into this concerned the harmless vibrios which are often found in water-supplies or in man himself - "vibrios which are morphologically and often biochemically indistinguishable from true cholera vibrios" and which can only be distinguished from them by serological tests (Field. Service Hygiene 1945). Much work has been done on possible changes in the nature of these vibrios, but without conclusive results.

The house-fly, and poor sanitation.

The house-fly has already been mentioned several times. Ross (1928) suggested that in some circumstances at least flies might be the most important factor in conveying the vibrio cholerae. Gill and Lal (1930-31), having worked on the epidemiology of cholera considered in relation to the house-fly, carried out some incomplete but suggestive experimental work to see whether the fly might be more than a mere mechanical transporter of infection, analogous to the platinum loop of the laboratory, but in fact a true host for the disease; this latter possibility migh have profound implications for the problem of the reservoir of infection in the endemic areas. Even lacking this final proof from the laboratory, the epidemiological part of the work does seem clearly to incriminate the house-fly, even if only in the lesser role. In the outbreak in Kasur Town already mentioned (p. 151),

the scattered incidence was not suggestive of direct infection from sick to healthy. Sewage disposal was ill-organised, but coprophagy through contamination of food or drink by fingers or dust seemed also inconsistent with the scattered pattern of case incidence. In refuse tips, the cholera vibrio can only live for a limited time away from living tissues. On the other hand, flies find there a suitable breeding ground, and when they go forth in search of food, seem to offer the type of constant but relatively light increment of infection that typified the outbreak. It is suggested that the recognition of cholera as an insect-borne disease is as important as any measure regarding water-supply, inoculation or control of pilgrim centres, and the urgency of the case for an attack on poor sanitation is urged. In Calcutta, again, cholera vibrios were found in 19 per cent of flies in sample catches, and 17 per cent of cockroaches.

The Manipur Valley is one of the few areas of India where there is an indigenous system of latrines - pit latrines covered with lattice work of bamboo (Chandler 1926-28). But some 90 per cent of the population live on or very near the rivers, and the river banks are used for defaecation despite the existence of latrine as well as for the washing of clothes including those of cholera patients. Faeces are thrown into the water or put as manure on to vegetable gardens nearby. Thus there is a custom of use of latrines on which reforms might be founded, but there is no doubt of the direct incrimination of poor disposal of faeces, along with other factors, in a recent serious epidemic (Pandit etc. 1936).

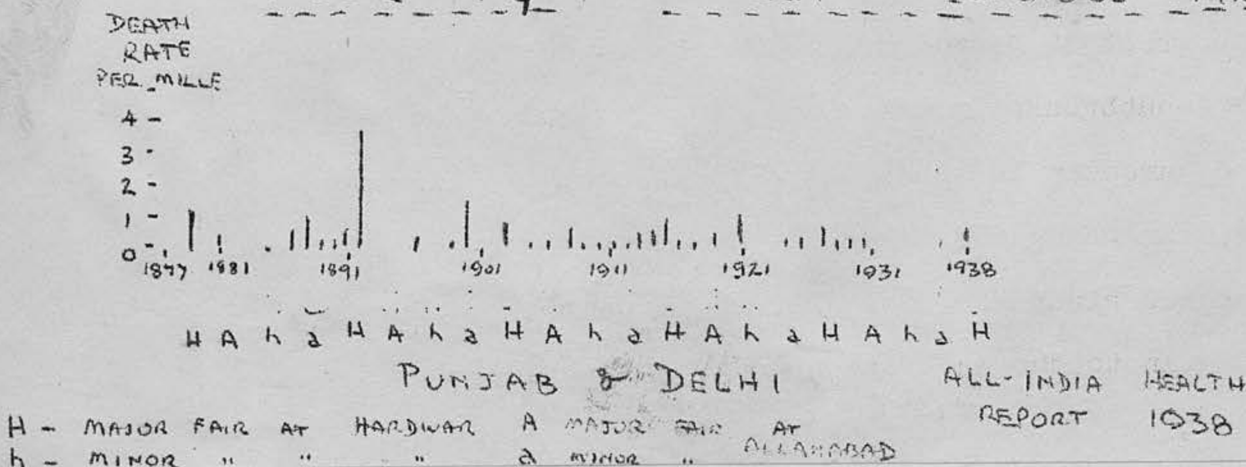
With regard to the contamination of foodstuffs, Rogers pointed out in 1911 that acids are hostile to vibrio cholerae, and thus the hydrochloric acid and peptin of the gastric juices will often destroy the ingested vibrio if the organism is not protected by being eaten in particular forms (or unless the acids be weak); this doubtless accounts for the capriciousness of the disease in an exposed population. The relative suitability of certain foodstuffs as media for the cultivation of the vibrio has been investigated with special reference to their relative roles in the dissemination of the disease (Lal etc. 1926) Among various tentative and suggestive findings, they have one firm conclusion - that articles containing salt, and either animal or vegetable protein, are specially suitable for the growth of the vibrio, thus meats, cooked pulses etc. head the list of potentially dangerous foods.

Pilgrimages and other movements of population

Visitors to an endemic area have long been recognised as peculiarly susceptible to infection (Rogers 1911).

Religious pilgrimages in India are particularly associated with cholera outbreaks, since they combine the mingling of cholera 'carriers' with large populations of susceptibles, living in camp under insanitary conditions, with ceremonies some of which the outsider feels might almost have been specially designed for the dissemination of cholera. The authorities have, of course, long been alive to the problem, and have increasingly tried at least to reduce the numbers of infectious cases arriving, and to

FIGURE 49 - CHOLERA & RELIGIOUS FAIRS



49 Cholera & religious fairs at Hardwar, graph...

limit the spread of infection in and from the pilgrim centres. The possibility of compulsory inoculation of pilgrims has been considered on many occasions (e.g. Central Advisory Board of Health 1940, and Bhore Report 1946).

Rogers (1928) has compiled a valuable historical survey of the great pilgrim centres and outbreaks associated with them. He pictures the crowding in of pilgrims numbering from one to two million, to camp in the neighbourhood of Hardwar on the occasions of the great 12 yearly fair which is so closely associated with cholera outbreaks in the north-west of India (see graph fig. 49. opp.); the packed humanity in the bathing enclosure, the slimy deposit on the banks, including the ashes of the dead brought to be scattered by the sacred river, and the excreta of pilgrims dying of cholera, carried in to the water to accomplish the object of their journey before they die; the bathing and the obligatory drinking of water; the worsening in dry years when the flow in the sacred pool is less. He relates the ups and downs of high and subsequently widespread cholera incidence partly to precautions against the disease, but more to higher or lower humidity, favouring or inhibiting the activities of the vibrio. For the fair is held in late March or early April, at a time when the crucial humidity may or may not be reached. And he points to years in which the infection may be dispersed back along the pilgrim routes, but simply to smoulder until an increase of humidity allows it to flare up in epidemic form.

The important fair at Allahabad, on the other hand, is held in February. Local outbreaks result, and cholera may spread east to Bengal, like an import of coals to Newcastle, but not to the Punjab where the crucial degree of humidity is lacking as yet.

Puri had long the highest cholera incidence in all India, associated with the crowding in of almost a million pilgrims to the small town for the Jugganath festival - an influx of 'carriers' and 'susceptibles' into conditions of rainfall, temperature and humidity favourable to the vibrio. (One might take count also of the favourable saline and organic content of the deltaic waters). The infection spreads north-east into Bengal, south-west into Madras to some extent, and notably again north-westward by Chattisgarh (the Middle Mahanadi) to the severely epidemic area of Central Provinces. The effect of railways has been somewhat to reduce the purely local outbreaks and to disseminate the infection more quickly.

Other pilgrim centres of note are Pandharpur in eastern Bombay, which has caused epidemics elsewhere in Bombay and in Central Provinces - whose vulnerable relation with several endemic areas containing pilgrim centres now becomes clear. Nasik, to the north-east of Bombay City, has a great although rather infrequent festival. And there are numerous less important but still considerable fairs held in various parts of Madras. Once an epidemic has been started at a large fair, quite small and local cattle or religious fairs may carry on the work of disseminating the infection, and they are more difficult for the authorities to supervise.

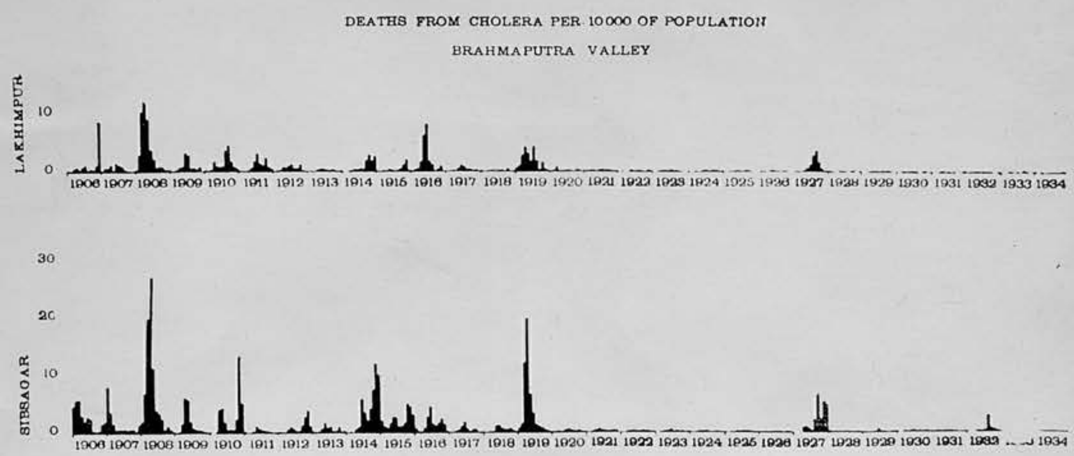
Rogers believes that the main effect of the increased speed of communications has been to allow an epidemic to sweep right across an epidemic area in one year, in which it exhausts the supply of 'susceptibles' for the time being, compared with the two years sometimes taken for that process in former times.

The intermingling of the populations of two villages at the elaborate marriage feasts is well-known to play a great part in the human chain of cholera infection which can often be traced in an epidemic (Punjab Health Report 1935, Rogers (1928) and many other references). It is almost universal for the head of the family to seek a wife for a boy or young man only from girls of suitable caste from outwith the family's own village. Religious rice feasts, then funeral feasts until these latter were curtailed, were incriminated in the early stages of a severe epidemic in the Manipur Valley (Pandit etc. 1936). Other examples of this kind of mingling of population and spread of infection have already been briefly cited in this discussion.

The influence of migration on cholera may be studied in Assam. In 1919 Assam had two great epidemics, associated with the inflow of labour, especially heavy at that time as a result of widespre famine and disease - the aftermath of the influenza pandemic of the previous year. Thereafter, however, inoculation and close supervision of immigrant labour for the tea estates, at the recruiting centres in Bengal and Bihar, halved the cholera mortality compared with the endemic areas (Morison etc. 1934).

50 Cholera in Brahmaputra valley of Assam, before and after intr‹duction of compulsory inoculation against cholera of workers arriving on tea estates......................................

GRAPH.



A remarkable diminution in cholera incidence in areas with 25 per cent of its population on tea estates followed when compulsory inoculation at the recruiting centres was initiated as shown in figure opp. [illegible] (Rice 1933). Since then, epidemics have begun in the villages, not on the tea estates. But there are other migrations to be considered - e.g. the seasonal movement of the Bihari fishermen referred to on page 151, who come from October or November to March, April or May; and there are harvest labourers from Bengal, who come in March and April for the 'aus' crop, and in October and November for the 'bora' crop. When these labourers are on the move up-country in search of work, cases of cholera can be seen on the boats. The off-season for cholera is the flood-season, when four or five hundred people to the acre are crowded on the meagre island-sites above the flood level, along with cattle, sheep, goats and dogs, in almost unbelievable congestion, and sometimes with the homes almost touching each other. In these circumstances, an explosive outbreak would surely follow if a 'carrier' were present. But cholera in fact increases after the floods, and while the change from the great dilution of any infection during the floods to the more stagnant conditions as they retreat may be important, the rise also coincides with the influx of labourers in autumn. There is a fall in January and February, in the cool months, but the rise in March coincides with the spring inflow of labour. There is one further group of seasonal immigrants mentioned - earth-workers from Bihar and United Provinces, who come presumably to repair embankments etc., and whose cool-weather stay in Assam approximately coincides with that of the Bihari fishing groups.

A strong case, for Upper Assam's being regarded as an epidemic and not an endemic area rests on the seasonal and temporary migration of labour. More tentatively, Rice suggests that this ebb and flow of seasonal labour mainly from Bengal and Bihar, into Assam and back again, and at times so nearly coinciding with the upsurge of cholera both in their permanent homes and in Assam, may be fundamental in determining the differing seasonal incidence in this area where purely climatic factors are favourable for most of the year. Thus in 1933 in the Surma Valley, there was a slow advance of sporadic cases upstream in the monsoon, but without association with the flooded rivers. In September, it reached Cachar, where it flared into a sharp epidemic as the floods receded, and thereafter moved downstream, not so much directly waterborne as carried by relatively few watermen in their boats and on rafts; it reached Bengal, as Rice puts it, 'in scheduled time to start the annual epidemic'. The suggestion is that similarly but on a much larger scale, the infection is carried to and from Assam by the considerable movement of temporary and seasonal migrants described.

Migration has also been investigated in relation to the great movements of seasonal and temporary migrants to Ceylon and to the problem of whether healthy carriers of cholera do exist, or whether the incubating, ill or convalescent patient is the only source of cholera. Actually, the two views have been, tentatively reconciled by Nicholls (1934-35). The change from sporadic cases to the flaring up of an epidemic may be related not only to the acknowledged factor of gross contamination of water supplies, but also to a change in the virulence of the vibrio by rapid passage through several patients at a time when their resistance is low - i.e. among people emigrating to Ceylon because of economic stress at home in Madras, and undergoing hardships while travelling, notably during rough crossings over Palk Strait.

<u>The 'carrier' problem and the human reservoir of infection</u>

Some theories concerning these problems have already been touched on, but there is some literature dealing with them more directly.

Rogers' early text-book (1911) stressed the importance of the state of general health of the exposed population. Chills, diarrhoea, or other cause of congestion of the intestine are believed to be predisposing causes; fasting is thought to be a factor, and Muslims to be peculiarly liable to attack during the month of Ramazam which is not a seasonal but a shifting fast. Otherwise Hindus are thought to be more liable to the disease and to have a higher casemortality because of their generally poorer diet and nutrition. The duration of infection in humans is significant. Of the survivors of an attack of cholera 95 per cent are reported to be free from the cholera vibrio within a fortnight, and the remaining 5 per cent within six weeks. Less than .2 per cent of new cases can be infected from these 5 per cent, who are not, of course, true 'healthy carriers'. Hence it is arguable that the patient is the only real source of infection. (Saranjam Khan 1930).

Towns and villages

Finally the relations of cholera with the differing environments and social grouping of town and villages in different parts of India is a most important topic already mentioned to some extent, on which a little more material is available.

Reported urban mortality rates are higher than rural rates and Malhotra offers some comments (Punjab Health Report 1932). In rural areas particularly, different communities of differing customs may live their lives almost segregated one group from another, and in some such groups the mortality rates may be as high as in urban populations. There is no such thing as uniform risk of exposure to infection in any considerable population group; the ideal way to study the problem would be gather data in the field concerning smaller groups, urban and rural, which are more or less homogeneous in respect of 'personal contact with patients, the presence of flies in the immediate neighbourhood of infected houses, coupled with the peculiar conditions of water and food pertaining to a particular community.'

In Assam, many village populations are mainly of immigrant families, and therefore of very mixed castes and communities; these have been found less liable to be swamped by an epidemic wave compared with otherwise fairly comparable but more homogeneous village groups of Assamese people, of similar caste, housing and habits (Morison etc. 1933-34 and 1934-35). On the other hand there was a possible off-setting factor. Morison was working on the uses of the bacteriophage theory of D'Herelle and Malone which seemed of such promise at that time but whose utility now seems to be regarded as not proven, and he concluded that the several sources of water supply used by different communal groups within the mixed villages were less likely to be invaded by the benificent bacteriophage from convalescent patients compared with the Assamese village with its common source of water supply.

Appendix C - Statistical Method.

by Miss Elizabeth Gittus

Notation

Let i denote the District $i = 1 \ldots h$, $h - 208$

Let j denote the year, $j = 1 \ldots k$. $k = 20$.

In any category, e.g. death-rate from cholera, let x_{ij} be the variable in district i and year j; then the mean death-rate (1) for district $i = \frac{1}{k} \sum_j x_{ij} = \bar{x}_i$ and the variability in district i, measured by the standard deviation from $\bar{x}_i$ $= \sigma_{\bar{x}_i}$ say $= \left\{ \frac{1}{k-1} \sum_j (x_{ij} - \bar{x}_i)^2 \right\}^{\frac{1}{2}}$

Then $\bar{x}_i$ and σ_{x_i} are the statistics to be classified.

Method of Classification

This is described and illustrated in the text for both $\bar{x}_i$ and σ_{x_i}. It is a subjective method, determined for each category separately, on consideration of the overall distributions of $\bar{x}_i$ and σ_{x_i} and the relation between them.

A more theoretical approach is described in a publication by the Department of Economics and Statistics of the United Provinces Government (2). The author analyses mortality rates (from

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1. Unweighted means have been used throughout on the assumption that population changes within any one district have little effect on the district mean. Estimates of general means are, however subject to error.

2. Vital Statistics in United Provinces (A critical analysis of 40 years data) A.R. Sen., M.Sc., F.S.S. (London). Dept. Economics and Statistics, U.P. Govt. (1948).

cholera, smallpox and plague) in each district of U.P., over a period of 40 years and classifies district means and variability as high, normal or low. This method which is similar in principle for mean and variability, (i.e. standard deviation), is briefly as follows.

For each disease, the 40 years' data in each district is regarded as a sample from a parent population, which is assumed to be normal. The general mean is estimated and the fiducial range calculated from the 5% point of the distribution. District means which fall above, within or below this range are termed high, normal and low respectively.

This procedure has not been followed for two reasons. Firstly the present data covers 20 years only and in each category gives little support to the hypothesis that the parent population is normal; the overall distributions of $x_{\lambda j}$ exhibit varying degrees of skewness. Further, in the United Provinces study, the parent distribution is defined only in terms of the data that is to be classified. Therefore 5% of the observations i.e. district means may be expected to fall outside the fiducial range purely by chance. It is not possible to discriminate objectively between the random and the significant.

Calculation of $\bar{x}_{\lambda}$ and $\sigma_{x\lambda}$

For each category the rates $x_{\lambda j}$ were assembled in the form of a frequency distribution, firstly for all districts combined and then for each district separately. This method was chosen as the most convenient way of assessing the pattern of the overall distributions of $x_{\lambda j}$ and of calculating district means and variability.

To reduce the labour of calculating some 2000 values of σx_{λ} an estimate was derived as follows:-

It was found that distributions of $x_{\lambda j}$ for individual districts were seldom normal; more often the shape was rectangular or positive - skew. Considering two typical forms and their associated frequency curves:-

(i) rectangular $f(x) = 1/r$

(ii) triangular $f(x) = 2(r-x)/r^2$

when r is the range, expressions, in terms of r, for the standard deviation and the distance between the quartiles, d, may be derived for each probability distribution.

Distribution	σ/r	d/r
Rectangular	$\frac{1}{2}\sqrt{3} = 0.289$	0.50
Triangular	$\frac{1}{3}\sqrt{2} = 0.236$	0.183

Standard deviations were computed in the usual way for all districts for the categories cholera and plague. Two empirical relations between σ and r were fitted, by least squares to the cholera results:-

$$(i)\ \sigma = r\alpha + \left(\frac{1}{2} - \frac{d}{r}\right)\beta$$

$$(ii)\ \sigma = r\left[\gamma + \left(\frac{1}{2} - \frac{d}{r}\right)\delta\right]$$

The first was abandoned since it was too insensitive to changes in r and gave normal equations that were ill-conditioned. The second, when γ and δ were determined, took the form:-

$$\sigma = r\left[0.294 - \left\{\frac{1}{2} - \frac{d}{r}\right\} 0.154\right]$$

or $\sigma = r x$ where, knowing r and d/r, x could nearly always be read off directly from a small table.

This empirical relation gave the following results for the two distributions:-

Distribution	actual σ/r	estimated σ/r
Rectangular	0.289	0.294
Triangular	0.236	0.254

On the accompanying diagram, estimated and calculated standard deviations for the plague data are plotted against each other. There are few large deviations from the line of agreement and still fewer that would result in an error of classification.

Random checks have been made in all the other categories. A further check on the mean square of the estimate is described below.

Analysis of Variance

For each category, an analysis of variance has been tabulated and used, not to test the homogeneity of the between-district and within-district estimates of variance, since the overall distributions are not normal, but to provide checks on the variance of the distribution of district means and on the average of the estimated within-district variance.

For if $\sigma^2_{\bar{x}_\lambda}$ be the variance of district means.

then $\sigma^2_{\bar{x}_\lambda} = \frac{1}{n-1} \sum_\lambda (\bar{x}_\lambda - \bar{x})^2 = \frac{1}{k}$ [between-district mean square]

If σ'^2_λ be the estimated within-district variance (i.e. derived from $\sigma = r x$)

and σ_{λ}^{2} be the actual within-district variance.

then $\frac{1}{h}\sum_{\lambda}\sigma'^{2}_{\lambda}$ may be computed and compared with $\frac{1}{h}\sum_{\lambda}\sigma^{2}_{\lambda}$

where $\frac{1}{h}\sum_{\lambda}\sigma^{2}_{\lambda} = \frac{1}{h}\cdot\frac{1}{k-1}\sum_{\lambda}\sum_{j}(x_{\lambda j} - \bar{x}_{\lambda})^{2}$

= [within-district mean square].

The results are summarised for all categories in the following Table, where

column (i) contains the general mean (unweighted - see footnote,(1) p.)

" (ii) contains the variance of the distribution of district means

" (iii) contains the standard deviation

" (iv) contains the coefficient of variation of the district means which gives a direct comparison, between the various categories of the amount of variability between districts. A low coefficient implies that the mean mortality rate is relatively uniform over all the districts, a high coefficient implies that the rate is high in certain localities. This clearly applies to death-rates from plague.

" (v) contains the within-district mean square $= \frac{1}{h}\sum_{\lambda}\sigma^{2}_{\lambda}$

" (vi) " " estimate mean $\sigma'^{2}_{\lambda} = \frac{1}{h}\sum_{\lambda}\sigma'^{2}_{\lambda}$

" (vii) " " ration between them.

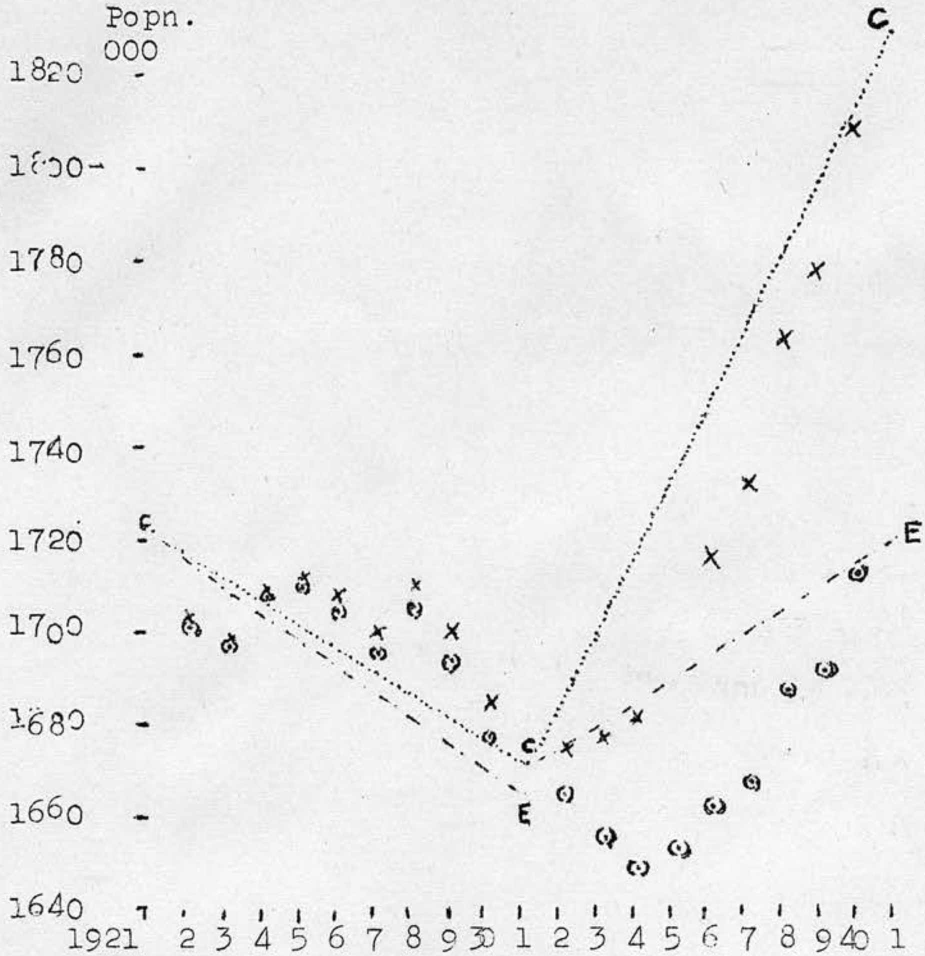
This provides a rough check on the efficiency of the estimate of σ_{λ}. It shows satisfactory agreement except perhaps for the category "birth-rate" where the estimated mean σ'^{2}_{λ} falls short of the actual value. Random checks suggest no ready explanation for this.

Summary of results

Category	General Mean	Analysis of Variance				Estimated variability	
		Between-districts			Within-districts		
	$\bar{x}$	$\sigma^2_{\bar{x}\lambda}$	$\sigma_{\bar{x}\lambda}$	$\sigma_{\bar{x}\lambda}/\bar{x}$	Mean σ^2_{λ}	Mean σ'^2_{λ}	$\frac{\text{Mean }\sigma'^2_{\lambda}}{\text{Mean }\sigma^2_{\lambda}}$
Birth-rate	34.7 per 1000	43.0	6.55	0.19	15.8	11.8	0.7
Death-rate	24.9 " "	24.6	4.96	0.20	27.8	31.9	1.1
Infant mortality	17.6 per 100 live births	13.5	3.68	0.21	8.6	8.9	1.0
Fevers	15.1 per 1000	31.6	5.62	0.37	12.4	13.8	1.1
Cholera	6.3 per 10,000	26.8	5.18	0.82	136.4	132.8	1.0
Smallpox	24.4 per 100,000	338.6	18.4	0.77	146.5	139.5	1.0
Respiratory Diseases	18.6 per 10,000	427.2	20.7	1.11	56.2	62.9	1.1
Dysentery	9.4 per 10,000	112.8	10.6	1.13	19.1	20.0	1.0
Plague	3.4 per 10,000	47.0	6.86	2.02	384.8	333.3	0.9

Appendix D

The estimates of population for the inter-censal years



On the accompanying example of the crude graphical technique employed, the points marked C are the Census figures for 1921, 1931 and 1941; while the straight (dotted) lines connecting these explain themselves. The District is Jessor in Bengal.

The point marked (.) for 1922 is the figure obtained by taking the 1921 census figure, adding on the births 1921 and subtracting the deaths for 1921. And so on. This process is not accurate, but was judged suitable for the purpose. Similar points were inserted for the years to . 1931, so that the point marked E in that year represents the estimated population, which may be compared with the Census figure. A straight (dot-and-dash) line joins C 1921 to E 1931.

The variations from the straight (dot-and-dash) line C 1921-E 1931 were measured for each year with dividers; similar variations were marked off in the corresponding years from the straight (dotted) line C 1921-C1931, and the points thus attained are those marked with a cross in the example. These points marked with a cross give the estimates of population for the inter-censal years used in the present work.

Semi-logarithmic graph paper would have given slightly better results in that the straight lines would then have represented an even rate of growth throughout the decade (e.g. 1 per cent per annum of the 1921 population gained by 1922, 1 per cent of the 1922 population gained by 1923 and so on). It was not used because the writer was ignorant of this quality of semi-logarithmic paper at the time of the work; and the volume of work is such that it could not be repeated.

B I B L I O G R A P H Y

The following select bibliography is in alphabetical order. In the case of papers, the pages in the journal concerned are quoted when available, along with an indication of the principal pages of the present work where they are used or referred to, using the present writer's initial to differentiate, thus L 15 etc. In the case of long papers and books, the particular pages used are indicated where possible, using the initial S for 'Source' , followed by the pages of the present work as before, so that such a reference might read L S 21/L 15.

1 Bates M. (1949) The Natural History of Mosquitoes L 108
Bhore Report - see under Reports

2 Blackburn C.R.B. (1948) - Observations on the development of resistance to Vivax malaria - Trans. Roy. Soc. Trop. Med. & Hyg. v. 42/2 117-162 L 127

3 Brahmachari B.B. (1923) - Verification of Vital Statistics in certain typical areas of Murshidabad. Calcutta, quoted by Sinton Records Mal. Surv. of I. 1935 v.5 p. 258/L 127

4 Buxton P.A. (1937-8) - Quantitative studies in biology of X. cheopis - I.J.M.R. XXVI 1937-8 505-30/L 50

5 Central Advisory Board of Health (1940) - Report on the possibility of compulsory inoculation of pilgrims against cholera L 155

6 Chandler A.C. (1926-28) I.J.M.R. S XIV 196/L 78, S XIV 461/L 82, S XIV 481/L 153, S XV 167-8/L 72, S XV 148/ L 85, S XV 169/L 75

7 Chhibber H.L. ( ) - Physical Geography of India S Fig.17 (Soils Map of Imperial Agricultural Institute, New Delhi) /L Fig. 8

8 Christophers S.R. (1925) - Malaria surveys for industry I.J.M.R. XIII/2 L 122

9 Christophers S.R. & Sinton J.A. (1926)) Malaria Map of I. I.J.M.R. XIV 173-178/L Fig. 23

10 Covell G. (1936) - Effects of Lloyd Barrage etc. - Records Mal. Surv. of I. VI S 411-2/L 120

11 Covell G. (194?) contribution to Boyd's 'Malariology' S Map of chief vectors of mal./L Fig. 39

12 Covell G. (1950) - Congenital Malaria - Trop. Dis. Bull. v.47 1147-67 L 125

13 Dunbar L. &c - Hysenteries of Madras - I.J.M.R. XVIII/1 L 33

14 Ejercito A. &c (1951) - Flight range of mosquitoes - Bull. W.H.O. 1951 663-71 L 112

15 Field Service Hygiene Notes India (1945) - S 297-300/L Fig. 38, S 293-4/L 103, S 333-4/L 152

16 George P.V. &c (1934) I.J.M.R. XXII/1 L 50 - Plague Inquiry in the Cumbum Valley

17 Geddes A. (1941) - Population change and variability in change G.J. v.98 L Chapter 11.

18 Geddes A. (1942) - Demographic Regions in I. G.R./L Chapter 12 + xxi

19 Geddes A. (1947) - -
Human Relations 1/2 L xvi
20 Geddes A. ( ) - Partially completed book on I./L Introd,
21 Gill C.A. (1927) - Forecasting Mal. - I.J.M.R. XV 265-76
L 116
22 Gill C.A. & Lal R.B. (1930-31) - Epidemiology of chol., especially transmission - I.J.M.R. XVIII 1255 L 151
23 Hajra B.N. (1948) - Anti-mosquito operations Cuttack Town - I.J.Malariology v2/4 307-11 L 121
24 Hehir P. (1927) - Mal. in I. Especially Part I ppl 1-174
S 16-18/1 135a-135b
25 Henderson J.M. (1949) Man-made Mal. in I., I.J. Mal.v3/2-3
253-9 L 122
26 Hughes T.A. (1933-4) Cirrhosis of Liver in Pjab. - I.J.M.R.
XXI 353-60 L 127
27 Imperial Gazeteer of India - L. Chapter 12.
28 Iyengar M.O.T. (1930) - Jungle & Mal. in Bengal - I.J.M.R.
XVIII/1 L 117
29 Iyengar M.O.T. (1931) - I.J.M.R. XIX/1 - Absence of Mal. in Salt-water Lake basin - L 111
30 Iyengar M.O.T.(1932) - Anopheline breeding in relation to season - I.J.M.R. XIX/3 L 115
31 Iyengar M.O.T. (1933) - Seasonal incidence M.T. B.T. & Q.
Mal. - I.J.M.R. XX/1 - L. 115
32 King, L. ( ) - The World's Plain-lands - Q.J.G.S. cvi
L viii
33 Kingsley Davis (1950) - The Population of India & Pakistan
S figs. ....& 55/L xxii, 94 & Figs. 17 & 18.
34 Lal R.B. &c - Foodstuffs & chol.; transmission - I.J.M.R.
XIV 245-9 L 154-5
35 May J.M. (1951) - World Map Cholera - G.R. /L 136-8,140,142
36 May J.M. (1951) - World Map, Mal. Vectors - G.R./L 107
37 Mayo K. (1927) - Mother India S Chap.8/L 18
38 Meteorological Atlas of India (1906) - Lxvi, 138
39 Morison J. &c - Bacteriophage & Chol. - I.J.M.R. XXI 791-909
L 151, 162
40 Morison J. &c - Bacteriophage & other treatments I.J.M.R.
XXII 317-339 L 162
41 Nicholls L. (1934-5) - Carriers of Chol entering Ceylon -
I.J.M.R. XXII 713-44 L 160
42 Pandit C.G. &c - Particular outbreaks of Chol.- I.J.M.R. XXIV
37-64 L 157
43 Pandit S.R. &c. - Vibrios in natural waters in Assam -
I.J.M.R. XXVI/1 L 150
44 Passmore R. (1948) - Nutritional disease of I. - TS 63/1 21
45 Pruthi H.S. - Hydrogen ions & temperatures & anopheles -
I.J.M.R. XIX/2 L 119
46 Powell B.H.Baden (1896) - The Indian Village Community -
Especially chapters 1 & 2 L chapter 12.
47 Powell B.H.Baden (1908) - The origina & growth of Village communities in I. - L chapter 12.
48 Ramsay G.C. - Anophelin infectivity Cachar District -
I.J.M.R. XVIII 533 L 116
49 Read W.D.B. &c - V. cholerae in water - I.J.M.R. XXVII 1-40
L 148

Reports
50 Health Survey & Development Committee ('Bhore Report') (1946) S 100/L 40, S 113/L 155
51 Annual Reports of Public Health Commissioner to the Government of I. L 2 (General acknowledgement),
52 ---do.---(1933) S 82/L 38
53 ---do.---(1935) S 46/L 33, 55
54 ---do.---(1940) Mal. Map (Mal.Surv.of I.) /L Fig. 23
55 Report of the Public Health Admin. of Pjab. (1939 & 1940) L 15
56 ---do.---(1931) S 2-3/L 39
57 ---do.---(1932) S 12/L 161
58 ---do.---(1935) S 15/L 157
59 Rice E.M. - Epidemiology of Chol. especially Assam - I.J.M.R. XXIII 467-73 L 158-9
60 Rogers L. (1928) Incidence & spread of Chol. in I. - I.Med. Research Memoir No. 9 S 16-20/L 138-42, S 12/L147, S 41-9 L 146, S 63/L 157, S 162/L 157, L 145 (general remarks).
61 Rogers (1911) Cholera & its treatment - S 82-3/L160, S 64 & 85/L 154, S 64/L 148.
62 Rogers L. (c.1930) - Plague forecasting - reference in All-India Health Reports 1932 p.46/L 51
63 Rogers L. (c 1928) - Smallpox & climate in I. - quoted in I.J.M.R. XVI 583/L 55
64 Ross W.C. (1928) - Epidemiology of Smallpox - I.J.M.R. XV 951-64/L 146
65 Russell J. & Sundararajan (1928) - Epidemiology of Chol. in I. - I. Med. Research Memoir No, 12 L 142-6 & 147.
66 ---do.---(1929) -Epidemiology of Smallpox - I.J.M.R. XVI 559-638 L 55
67 Saranjam Khan (1929) - Chol. vibrios duration of life in Jumna water - I.J.M.R. XVI/4 L 148
68 ---do.--- (1929) - Chol. carriers - I.J.M.R. XVII/1 L 161
69 ---do.---)1929) - Reservoir of chol. " " L 140,161
70 Sharif M. (1951) - Plague in S. & C. Bombay and endemic centres in sub-continent - Bull. W.H.O. 1951 75-109 L 51
71 Shortt H.E. &c. - Pre-Erythrocytic stage of Plasmodium Falciparum - ~~Trans.~~ Roy.Soc. Trop.Med.& Hyg. 1951 405-19 L. 104 /(1938) /
72 Sinton J.A. &c - Man-made Mal. in I. - Health Bull.No. 22 L 122
73 Sinton J.A. - 1935-6 - What Mal. costs I. - Records Mal. Surv. of I. v 5 223-264 & 413-489, v 6 91-169, S 127-32/ L S 158-60/L 127-32
74 Stamp L.D. (1944) - Asia - Chapters on I./L Introduction
75 Strickland C &c - Sporozoite rates of anopheles in Terai I.J.M.R. XXI/1 L 107 (1933b)
76 ---do.--- (1933a) - A year's observations, infection of A. stephensi - I.J.M.R. XX/3 L 107
77 Thomson C.J. (1931)) Still-births & neo-natal deaths in I. I.J.M.R. XIX/2 L 19-20
78 Ukil A.C. (1946) - quoted in Bhore Report p. 100-1/L 40
79 Wei Y. (1949) - Absolute Humidity & Chol.in Shanghai Chinese Med. J. v. 67 177-83 (Trop. Dis. Bull. 1950 v 47 132/L 141)

80 White R.S. (1948) - Mal. Transmission, modern evolutionary theory and mosquitoes - I.J.Mal. 1948 v 2/1-2 13-33 (Trop Dis. Bull. 1949 v. 46 605/L 111)
81 Wilson D.B. etc. (1950) - Hyperendemic Mal. - Trop.Dis. Bull. v. 47 1677-97/L 126
82 Yacob M. &c (1947) Mal. & spleen rates in Pjab. - I.J.Mal. v.1/4 469-89 (Trop.Dis. Bull.1949 v. 46 110/L 117)
83 Williamson A.V. (1931) - Variability of Rainfall in I. G.R. L xv
84 Wilson D.C. - (1929-30) - Osteomalacia - I.J.M.R. XVII 339-50 /L 19
85 ~~Williams A.Hyatt (1950) - A psychiatric Study of~~ I. Soldiers in the Arakan v XXIII 130-181 /L xxii & 100

B.J.Med. Psych. - British Journal of Medical Psychology; G.J. - Geographical Journal; G.R. - Geographical Review; I.J.Mal. - Indian Journal of Malariology; I.J.M.R. - Indian Journal of Medical Research; G.J.G.S. - Quarterly Journal of the Geological Society; Recods of Mal.Surv. of I. - Records of the Malaria Survey of India.

The following Index lists the works referred to in the preceding bibliography under their subjects. In this index, the numbers given refer to the serial numbers in the bibliography:-

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THE UNIVERSITY OF LIVERPOOL

27 July 53

Dear Mr. Wood,

Binding of Thesis

Thank you for your letter of 17th. inst. As you say, it was only shortage of time which caused me to submit the thesis in springback folder — the binders here reckoned it would take a fortnight which would have prevented the work going forward this summer.

Do please get Messrs. Duncan to do the work & send the bill to me.

Yours sincerely,

A. L. S. Kearsworth

9th July, '53

DEPARTMENT OF GEOGRAPHY
HIGH SCHOOL YARDS
EDINBURGH

University of Edinburgh

Ph.D., 1953 (A.T.A.)

Learmonth. Ph.D.

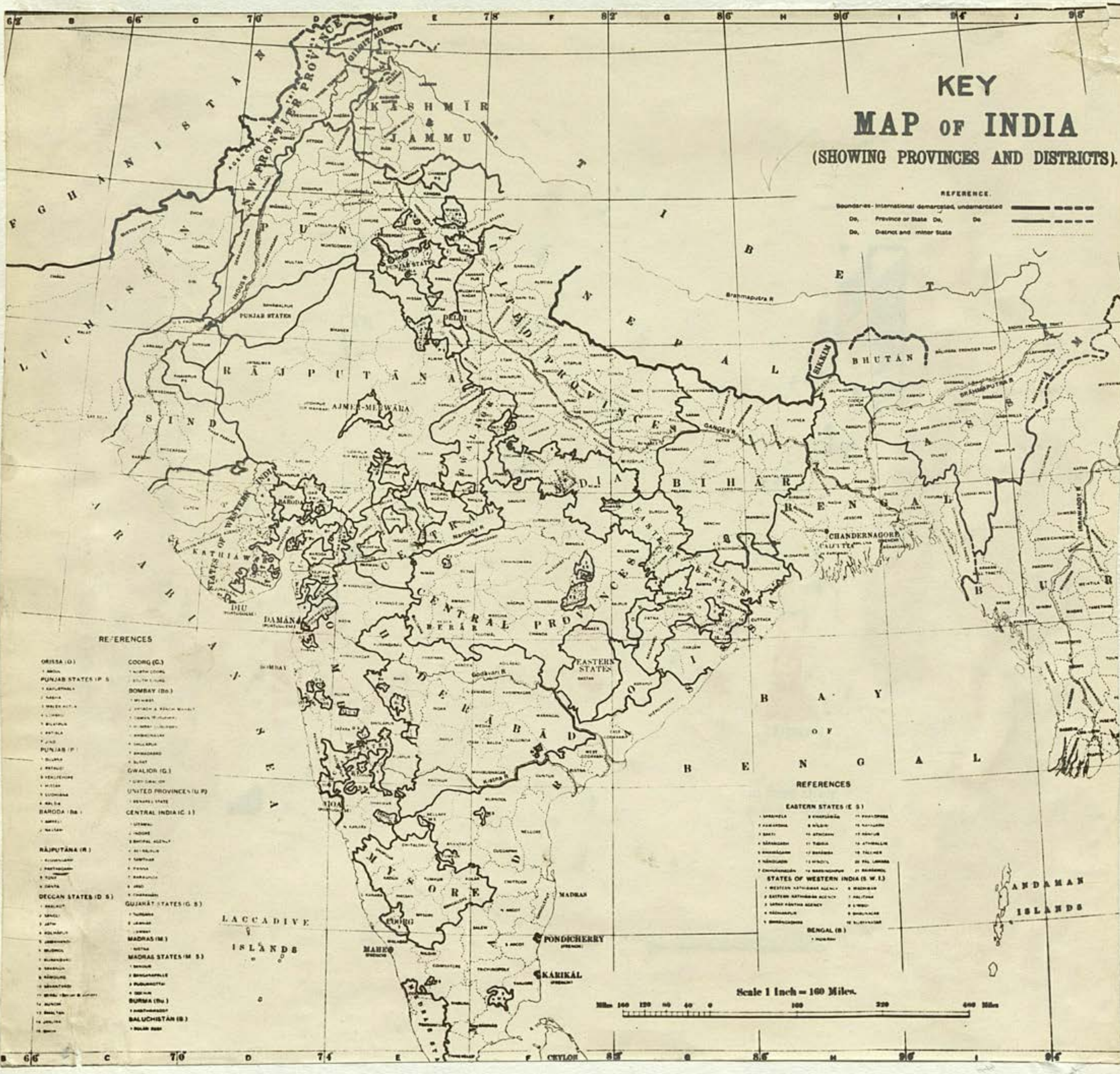
Dear Mr Wood,

Here's Copy No. 2, with (inserted) 3 corrected pp.; and envelope containing another copy of each of the 3 pp., to insert in Copy No. 1. Could you please see to No. 1, inserting the enclosed, and returning the 3 uncorrected pp. (from No. 1.) to me, for Learmonth?

(Similar instructions on envelope.) Binding could then proceed.

Yours sincerely,

A. Geddes


KEY
MAP OF INDIA
(SHOWING PROVINCES AND DISTRICTS).
REFERENCE.
Scale 1 Inch = 160 Miles.
KASHMIR & JAMMU
GILGIT AGENCY
N.W. FRONTIER PROVINCE
AFGHANISTAN
BALUCHISTAN
PUNJAB
PUNJAB STATES
RAJPUTANA
AJMER-MERWARA
SIND
DELHI
UNITED PROVINCES
NEPAL
TIBET
SIKKIM
BHUTAN
ASSAM
BIHAR
BENGAL
CHANDERNAGORE
CALCUTTA
CENTRAL INDIA
CENTRAL PROVINCES
EASTERN STATES
BERAR
ORISSA
HYDERABAD
BOMBAY
DIU
DAMAN
GOA
MYSORE
COORG
MADRAS
PONDICHERRY
KARIKAL
MAHE
LACCADIVE ISLANDS
ANDAMAN ISLANDS
ARABIAN SEA
BAY OF BENGAL
BURMA
CEYLON
REFERENCES
EASTERN STATES (E.S.)
STATES OF WESTERN INDIA (S.W.I.)
BENGAL (B.)
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DECCAN STATES (D.S.)
COORG (C.)
BOMBAY (Bo.)
GWALIOR (G.)
UNITED PROVINCES (U.P.)
CENTRAL INDIA (C.I.)
GUJARAT STATES (G.S.)
MADRAS (M.)
MADRAS STATES (M.S.)
BURMA (Bu.)
BALUCHISTAN (B.)